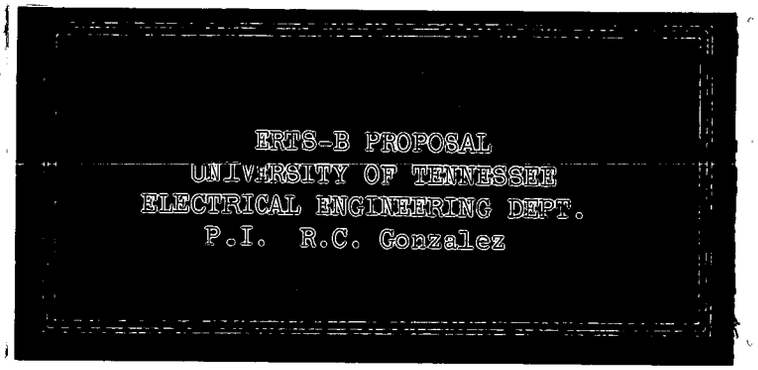
2



26 January 1973

ERTS-B IMAGERY INTERPRETATION TECHNIQUES IN THE TENNESSEE VALLEY*

Submitted by:

Principal Investigator: Dr. Rafael C. Gonzalez
Assistant Professor of Electrical Engineering
The University of Tennessee
Knoxville, Tennessee 37916

Agency: Electrical Engineering Department
The University of Tennessee
Knoxville, Tennessee 37916

*This proposal is a continuation of ERTS-A project No. NAS5-21875 bearing the same title and under the direction of Dr. R. E. Bodenheimer

TABLE OF CONTENTS

Investigation Synopsis

Part I - Investigation Description

Primary Discipline/Sub-Discipline Code 8ABCDEH (15)

Secondary Discipline/Sub-Discipline Codes 1. 2ACEI (15) 2. 4ABCJKM (15)

Proposal Title:

ERTS-B Imagery Interpretation Techniques in the Tennessee Valley (110)

Abstract:

The proposed investigation is a continuation of an ERTS-A project bearing the same title. Its principal missions are to serve as the principal supporter on computer and image processing problems for the multidisciplinary ERTS effort of the University of Tennessee, and to carry out research in improved methods for the computer processing, enhancement, and recognition of ERTS imagery. (800)

Proposed Duration of Investigation (months) 18 Proposed Start Date April 1, 1974

Investigation Synopsis

Part II - Personnel Information

Principal Investigator

Name: Dr. (title) Rafael (first name) C. (middle initial) Gonzalez (last name) (30)

Affiliation: University of Tennessee (organization) (30)

Mailing Address: Ferris Hall (branch, bldg., or street)

Knoxville, Tennessee 37916 (city) (state) (zip) (155)

Phone No.: (615) 974-2579 (12) Extension: 2579 (4) Telex/TWX no.: N/A (10)

Other Proposals Submitted? (yes/no) No

List other proposal titles and associated numbers:

N/A

(110)

Co-Investigators

1. Name: Dr. (title) Robert (first name) E. (middle initial) Bodenheimer (last name) (30)

   Affiliation: University of Tennessee (organization) (30)

   Mailing Address: Ferris Hall (branch, bldg., or street)

   Knoxville, Tennessee 37916 (city) (state) (zip) (155)

   Phone No.: (615) 974-2294 (12) Extension: 2294 (4)

Investigation Synopsis

Part II - Personnel Information (cont'd.)

2. Name: N/A (30)
(title) (first name) (middle initial) (last name)

Affiliation: N/A (30)
(organization)

Mailing Address: N/A
(branch, bldg., or street)

N/A
(city) (state) (zip) (155)

Phone No.: N/A (12) Extension: N/A (4)

Project Coordinator (if any)

Name: N/A (30)
(title) (first name) (middle initial) (last name)

Affiliation: N/A (30)

Mailing Address: N/A
(branch, bldg., or street)

N/A
(city) (state) (zip) (155)

Phone No.: N/A (12) Extension: N/A (4)

Government Agency Coordinator (if any)

Name: N/A (30)

Agency: N/A (30)

Mailing Address: N/A
(branch, bldg., or street)

N/A
(city) (state) (zip) (155)

Phone No.: N/A (12) Extension: N/A (4)

Investigation Synopsis

Part II - Personnel Information (cont'd.)

Test Site Coordinator (if any)

Name: N/A (30)
(title) (first name) (middle initial) (last name)

Affiliation: N/A (30)
(organization)

Mailing Address: N/A
(branch, bldg., or street)

N/A
(city) (state) (zip) (155)

Phone No.: N/A (12) Extension: N/A (4)

Check this space if there are continuation sheets: _____

Investigation Synopsis

Part III - Proposal Information

Management/Organizational Structure

Is Research Staff Organizational Structure a Consortium? (yes/no) No

Number of institutions in consortium: N/A (2)

List the names of each institution, country it represents, and staff size.

1. Institution N/A (30) Country _____ (30) Staff Size _____ (2)

2. Institution N/A (30) Country _____ (30) Staff Size _____ (2)

3. Institution N/A (30) Country _____ (30) Staff Size _____ (2)

If not a Consortium, indicate whether PI/Tech Staff is U. S., non-U. S., or combination of U. S. and non-U. S. Personnel 1

(1=U. S., 2=non-U. S., 3=U. S. and non-U. S.)

Proposal Cost Data

Funding

Is NASA funding required? (yes/no) Yes

How much NASA funding?

Fiscal Year '74	Fiscal Year '75	Fiscal Year '76	Total
$ 8,886 (10)	$ 37,500 (10)	$ 9,277 (10)	$ 55,663 (10)

Is other funding required? (yes/no) No

Amount of other funds

Fiscal Year '74	Fiscal Year '75	Fiscal Year '76	Total
$ N/A (10)	$ N/A (10)	$ N/A (10)	$ N/A (10)

Sources of other funds:

N/A (150)

Investigation Synposis

Part III - Proposal Information (cont'd)

Equipment

1. Data Collection Platforms:

Are Data Collection Platforms needed? (yes/no) No

If so, how many? N/A (3)

Are DCP's being used in ERTS-1? (yes/no) No Number N/A (3)

List platform sensors and/or interface equipment (e.g., barometers, thermometers, etc.) in the space provided:

N/A

(250)

2. Automatic Data Processing (ADP) Equipment:

Is new or additional ADP Equipment needed? (yes/no) No

Estimated cost: $ N/A (10)

Description: N/A

(150)

3. Government Furnished Equipment (GFE):

Is GFE needed? (yes/no) No

New or Existing Equipment: N/A (1 = new; 2 = existing)

Owner Agency: N/A (30)

Description: N/A

(150)

4. Other Capital Equipment:

Is other capital equipment needed? (yes/no) No

Provided by: N/A (100)

Type of equipment: N/A

(150)

Approximate cost: N/A (10)

Investigation Synopsis

Part III - Proposal Information (cont'd)

Are you (the proposer) a selected ERTS-A investigator (yes/no) Yes

Is this investigation a continuation of an ERTS-A investigation? (yes/no) Yes

GSFC Contract number NAS5-21875 GSFC I.D. number UN 654

Will you be using equipment from a previous ERTS-A investigation in this ERTS-B investigation? (yes/no)

Yes

Relationship to Other Investigations

Are you aware of other ERTS-B investigations in the same discipline/sub-discipline(s) and/or with the same or nearly the same geographical location of test sites as your investigation?

(1 = same discipline/sub-discipline, 2 = same geographical area for test sites, 3 = both). 3

Are you aware of other ERTS-B investigations with the same or similiar objectives as your investigation? (yes/no)

No

List the name(s) of the principal investigator(s) and/or the organization(s)

H.R. DeSelm, Botany Dept. Univ. of Tenn, Knoxville

J.B. Rehder, Geog. Dept., Univ. of Tennessee, Knoxville

L. Parks, Inst. of Agriculture, Univ. of Tennessee, Knoxville

(150)

Part IV - Product Requirements

Product Requirements Information

Is imagery required? (yes/no) No

U. S. and/or non-U.S.: N/A (1=US, 2=non-US, 3=both US and non-US)

Is repetitive coverage required? (yes/no) N/A

Are there any seasonal constraints? (yes/no) N/A

Are there any cloud cover constraints? (yes/no) N/A

Remarks (indicate seasonal, cloud cover or other coverage constraints)

N/A

(150)

Number of test sites: N/A

Location of test sites (state(s) or country): 1. N/A

2. 3.

4. 5. (30 each)

Check this space if there are continuation sheets:

Aircraft Support

Are aircraft data flights needed? (yes/no) No

Provided by whom? N/A (30)
(NASA, Department of Defense, Private Contractor, etc.)

Number of flights required: N/A

Purpose of flights (e.g., underflight, G.T.) N/A

(150)

Ground Truth Data

Is ground truth data required? (yes/no) No

Type of ground truth support: N/A
(1 = Field Team
2 = Data Collection Platform
3 = Existing System)

Other ground truth equipment needed? (yes/no) No

Type of equipment: N/A

(150)

Approximate Cost: N/A

Investigation Synopsis

Part IV - Product Requirements (Cont'd.)

If test site is non-U.S., has approval been obtained from host country for acquiring ground truth?
(yes/no) N/A Copy Attached (yes/no) N/A

Are there EREP* requirements relating to this investigation? (yes/no) No

Supplemental Data Requirements

Are there any supplemental data requirements? (yes/no) No

Type:

1. Standard Catalog: N/A (1 = U.S., 2 = non-U.S., 3 = U.S. and non-U.S.)
2. Microfilm: N/A (1 = U.S., 2 = non-U.S., 3 = U.S. and non-U.S.)
3. DCS Catalog: N/A (1 = U.S., 2 = non-U.S., 3 = U.S. and non-U.S.)

* Earth Resources Experiment Package to be flown on Skylab missions

GENERAL INFORMATION

This proposal is one of four submitted by the University of Tennessee (Knoxville). The other three proposals, which are listed on page 16 of Part I, will be almost entirely dependent for their information processing needs on the computer and image processing efforts which form an integral part of this proposal.

Ever since the beginning of the University's activities in remote sensing of the environment several years ago, the Electrical Engineering Department has played the central role in problems dealing with machine manipulation of the data resulting from this research. It has been our experience that very efficient results are obtained by utilizing a central group capable of organizing and carrying out the necessary support and research in this particular aspect of our multidisciplinary effort.

Because of our background with THEMIS and ERTS-A research programs, the University of Tennessee is in a unique position to make a real contribution to NASA efforts in the utilization of ERTS technology. Our work on THEMIS and ERTS-A has not only produced a versatile group of experienced investigators, but has also resulted in the acquisition of a considerable amount of sophisticated equipment, most of which is soon to be housed in the Image Processing Laboratory of the Electrical Engineering Department. The organization and facilities we now have will allow us to make maximum use of the data generated by the ERTS-B program.

PART I

TECHNICAL PROPOSAL

1.0 INTRODUCTION

1.1 SUMMARY ABSTRACT

The present proposal is a continuation of the project "ERTS-A Imagery Interpretation Techniques in the Tennessee Valley" under the direction of R. E. Bodenheimer, and supported by NASA (Project No. NAS5-21875) for a 15-month period. The missions of this ERTS-A task have been: (1) To serve as the principal supporter on computer and digital image processing problems to a body of multidisciplinary ERTS-A projects at the University of Tennessee†; and (2) to carry out research in the area of computer image processing and recognition. In terms of research benefits and objectives, the first mission identifies computer processing problems typical of a multidisciplinary group, while the second attempts to solve these problems and establish guidelines for a meaningful research program aimed at improving computer processing of ERTS imagery.

Under ERTS-B, our role in the multidisciplinary effort on the application of ERTS data will continue to be in the computer processing and interpretation of these data. The

---

†These NASA supported projects are:

"Ecological Applications of ERTS-A Imagery," H.R. DeSelm, Botany Department, University of Tennessee, Knoxville.

"Geographic Applications of ERTS-A Imagery," J.B.Rehder, Geography Department.

"Detection of Plant Diseases and Nutrient Deficiencies, Soil Types, and Moisture Levels," L. Parks, Institute of Agriculture.

experience gained with ERTS-A imagery will allow the ERTS-B project to be characterized by increased research in problems of computer image enhancement and recognition. We are presently in the process of installing a computer image processing research facility in the Department of Electrical Engineering (at no cost to NASA). While this research facility will have some impact on the ERTS-A effort, it will be of significant value in ERTS-B, not only in terms of our research, but also as a supporting tool for the other ERTS-B projects in the University.

Although the most productive phase of the ERTS-A research lies ahead due to delays in the launch date, it is already evident that a central group capable of providing support in computer techniques for digital image processing is a highly efficient approach to dealing with the problems that arise in a multidisciplinary effort dealing with the applications of ERTS imagery. This capability will continue to play a significant role in the ERTS-B continuation proposals submitted by the University of Tennessee[†]. These proposals, which are strongly oriented toward practical uses of ERTS data, will make increased use of the digital computer and related image processing facilities which are an integral part of this proposal.

1.2 BACKGROUND

The University of Tennessee has been involved in research

[†]These multidisciplinary proposals are:

"The Utility of Satellite Imagery in Vegetation-Ecosystem - Use Investigations," H.R. DeSelm, Botany Department.

"Geographic Applications of ERTS-B Imagery to Lanscape Change," J.B. Rehder, Geography Department.

"The Effect of Land-use and Other Watershed Characteristics Upon the Water Quality of Streams from the Watershed," L. Parks, Institute of Agriculture.

dealing with remote sensing of the environment for several years. The Tennessee Valley offers an ideal natural laboratory for this research because of its vast and controlled system of rivers and reservoirs, its land-use diversities, its natural resource potential, and its need for resource development.

Our expertise in the use of low and high-altitude flights, as well as satellite imagery, has been gained through a long-range THEMIS project and several ERTS-A tasks, as described in the previous section. These efforts are discussed below.

THEMIS background

Project THEMIS for Remote Sensing of the Environment at the University has been an interdisciplinary effort between Agriculture, Civil Engineering, Urban and Rural Planning, Geology, Botany, Electrical Engineering, and Geography. This effort has been supported by the United States Air Force. The remote sensing program is committed to the utilization of photography and thermal imagery as the means whereby the environment is sensed. Such diverse systems as diseased crops, soil surveys, forest inventory, urban planning, and water quality are being studied. All of these studies utilize data obtained from an air-borne camera and an infrared scanner.

The specific tasks of the Department of Electrical Engineering in this research have been:

- To develop the capability for processing infrared and conventional film data obtained from air platforms
- To develop digital analysis techniques compatible with the processing requirements of Project THEMIS
- To recommend and develop methods for information storage and retrieval.

ERTS-A background

The ERTS-A multidisciplinary group of the University consists of the departments of Geography, Botany, Agriculture and Electrical Engineering. The principal mission of this research has been to demonstrate useful potential applications for ERTS imagery and to establish the present limitations of this imagery within the scope of the projects mentioned in the previous section. As was explained in that section, the Electrical Engineering Department is the principal center for computational support and for research in image processing and recognition problems as related to the ERTS program. The scope of the interdisciplinary effort ranges from the application of ERTS-A imagery to detect the state of health of vegetation to the use of this imagery in the study of water resources and land use in the Tennessee Valley.

2.0 STATEMENT OF WORK

2.1 OBJECTIVES

The objectives of this proposal in terms of the overall ERTS multidisciplinary program at the University are:

- To conduct research in methods for the improved computer processing of ERTS data
- To conduct research in improved methods for image enhancement and display.
- To study automatic methods for pattern recognition as applied to ERTS data
- To coordinate the computer image processing and recognition tasks between disciplines
- To aid in the modification of existing software to meet the needs of each individual discipline
- To provide the expertise and interface necessary to extend the understanding of data obtained from airborne platforms to that obtained from earth-orbiting

platforms

- To develop feature extraction techniques for the use of each discipline
- To develop pseudo-color image enhancement techniques useful for each discipline
- To study topological properties of images for purposes of description and recognition
- To complete development of an image processing system (DEC PDP-11 supported) for data review, analysis, enhancement, and recognition (at no cost to NASA)
- To interface with personnel in NASA (Huntsville) who are carrying out research in related applications of ERTS imagery.

Several of these objectives are being partially met under our ERTS-A effort. For example, we are presently adapting some of the computer programs developed under THEMIS for use with ERTS-A data. Several smaller programs such as a 2-dimensional fast Fourier transform program are now being implemented. The image processing system is also being presently assembled and will be fully operational sometime in April, 1973. As was previously mentioned, however, the most productive phase of the ERTS research program still lies ahead.

2.2 APPROACH

The approach to this investigation is divided into three main areas: (A) computational and display techniques; (B) image enhancement techniques; (C) image recognition techniques. These topics are discussed below.

A. Computational and Display Techniques

ERTS-A imagery and tapes are presently being handled using primarily an IBM-360/65 computer (the complete data

handling system is discussed in detail in Section 3.0). In the ERTS-B phase of the research, however, we will be able to handle data in one of three possible ways: In the IBM-360/65, in an image processing computer, or by means of a real-time data interpretive system. The last two facilities are being presently assembled in the Electrical Engineering Department, as discussed in the next section.

The approach being taken to satisfy computational needs is to develop software packages which can be used in the form of routines. This is a necessity to satisfy a community of users which are relatively inexperienced in programming a digital computer. Examples of basic software which has been or is presently being developed and implemented are computer programs for:

- Histogram calculation
- Functional approximation
- Area calculations
- Calculation of basic statistical parameters

The following programs fall under the category of digital displays:

- Numerical tables and graphs
- Cal-comp output
- Line-printer plots
- Pictorial gray tone output

Finally, the following TV display capabilities (to be developed during the latter part of our ERTS-A effort and continued throughout ERTS-B) will be of significant value in the visual analysis of computer results

- 16-gray levels monochrome TV output
- 16-intensity levels pseudo color TV output
- 3-dimensional perspectives
- Computer-controlled color capabilities
- Real-time image operations such as density slicing and color display

The principal advantages of TV output are speed, quality of contrast, and color capabilities. By being able to digitally operate on an image and then displaying the results almost instantaneously, an investigator can dramatically increase his efficiency. Delays in turn-around time at big computer centers is a well-known handicap to investigators using the computer as a tool in their research. Some display capabilities will be on a real-time basis while others will be based on computer processing.

B. Image Enhancement Techniques

Image enhancement plays a central role in the highlighting and detection of significant events. A great deal of our present work on image enhancement is centered upon the 2-dimensional Fast Fourier Transform (FFT). The basic technique used is shown in Fig. 1. The function $f(x,y)$ represents the original input image, where (x,y) are the spatial coordinates of each point in the image and $f(x,y)$ is the intensity at that point. Application of the 2-dimensional FFT to $f(x,y)$ yields its transform $F(u,v)$ where (u,v) are the coordinates of the frequency plane. $H(u,v)$ may be considered a filter or mask which may be used to alter $F(u,v)$. For example, if it is desired to enhance edges in the original picture $f(x,y)$ (which are determined by high frequency components in $F(u,v)$), $H(u,v)$ may be used to boost the high frequencies in $F(u,v)$. Then, when the inverse transform of $H(u,v)$ $F(u,v)$ is taken, the result is $g(x,y)$ which is a picture similar to $f(x,y)$ but with enhanced edges. This approach is seen to be very powerful due to the tremendous variety of possible $H(u,v)$ that one may choose.

The same approach used in Fig. 1 can be used in a spatial-frequency pseudo-coloring scheme. The diagram which accomplishes this is shown in Fig. 2. As indicated in the figure, $f(x,y)$ is transformed. Then $F(u,v)$ is split into three

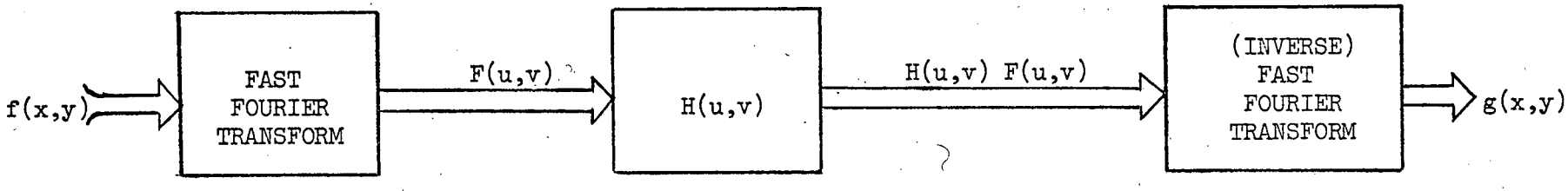


Fig. 1. Use of the Fourier Transform for Image Enhancement

frequency ranges by using three filters $H_1(u,v)$, $H_2(u,v)$, $H_3(u,v)$. The results of this operation are individually inverse-transformed, equalized (for more uniform color results) and, for example, fed into the Red, Green, and Blue inputs of the color monitor. The result is a picture where each color corresponds to a specific frequency range. This, of course, is only one of many possible color enhancement schemes. Another typical approach is to slice the intensity levels in a picture (density slicing) into several regions and then assign a different color to each region. Qualities which are completely undetectable in a monochrome picture can be convincingly brought out by this method.

Other methods for enhancing images are digital filtering and spatial gradients. We have effectively used gradient schemes to map out contours in infrared pictures of east Tennessee. These schemes will soon be applied to ERTS-A data in connection with the detection and monitoring of strip mining in the State.

It is worth mentioning that other ad-hoc techniques are often useful in image enhancement. Certain types of nonlinear transformations can sometimes be used to enhance or restore a specific image. Due to the variability and quality of ERTS data, however, we prefer the transform approach to image enhancement because of its applicability to a great variety of situations and also because of its relative simplicity of implementation.

We are presently evaluating an image analysis system which is capable of performing some image enhancement functions (particularly color) on a real-time basis. Although these functions are a subset of our present and projected capabilities, the real-time feature is extremely attractive for a coarse, quick look at significant volumes of data.

It should be pointed out that the above discussion is

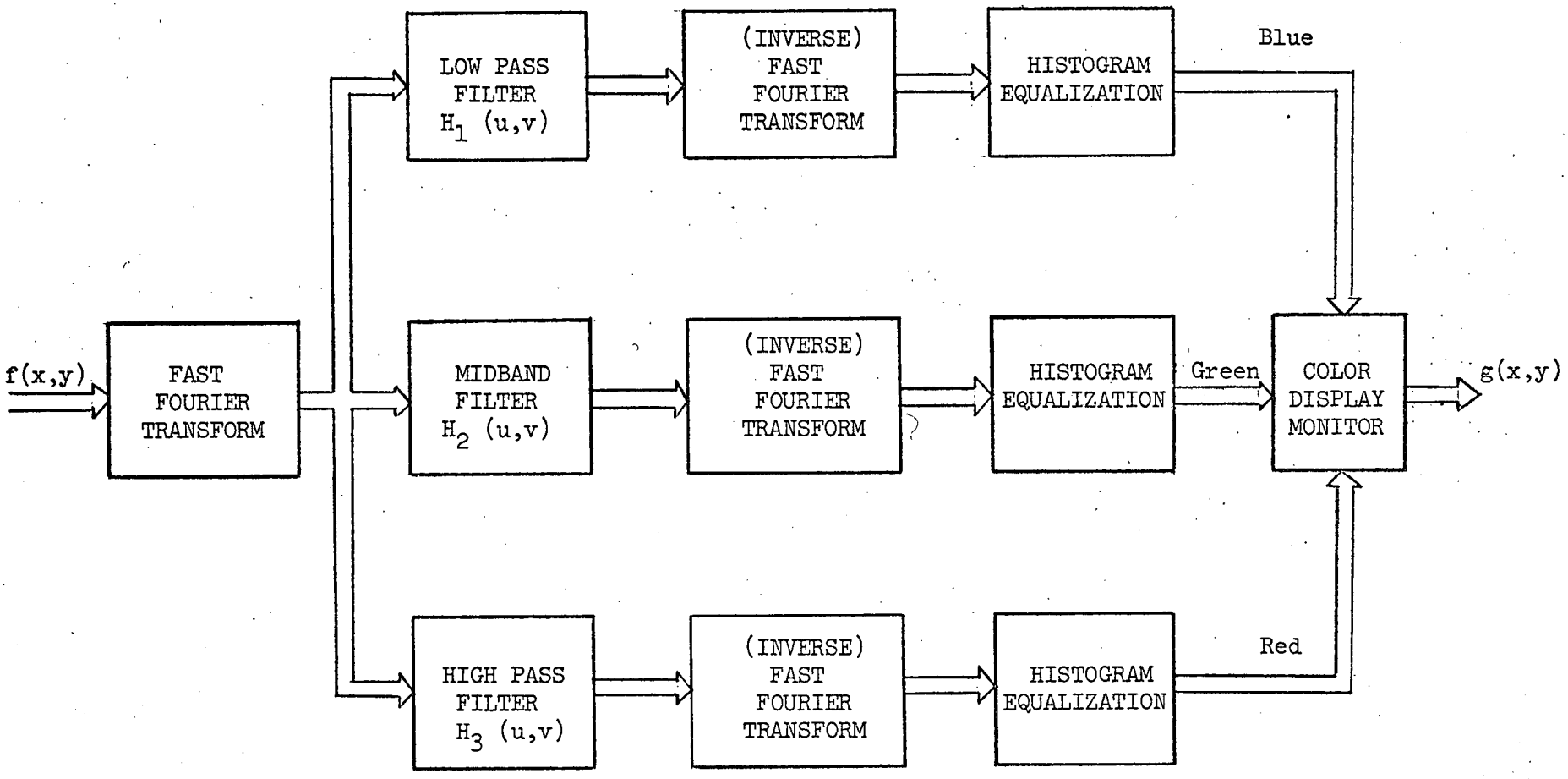


Fig. 2. Frequency-sensitive Pseudo-coloring Scheme

only intended to give the reader a general idea of the approaches which are either presently being taken or which will soon be implemented in our ERTS research; the techniques discussed should not be interpreted as being an exhaustive set of our activities in this area.

C. Image Recognition Techniques

One of the most important and difficult tasks in this field of research is the automatic recognition of patterns of interest in an image. It is well recognized that if we are ever to make substantial use of ERTS data, it is necessary that we develop automated recognition machines capable of processing this information on a routine basis. Research in this area is really in its infancy. However, some applications of pattern recognition methods have already produced encouraging results. The most salient of these applications in terms of earth resources is perhaps Purdue's LARSYS (Laboratory for Agricultural Remote Sensing System) facility for the automatic classification of crops from low-altitude multispectral photography. We will be involved in pattern recognition applications in this area in connection with the ERTS-B proposal "The Utility of Satellite Imagery in Vegatation-Ecosystems-Use Investigations" mentioned in Section 1.1.

In terms of national needs, one of the most pressing requirements for automatic recognition capabilities is in landscape change detection as applied to land use. We will be involved in research in this area in connection with the ERTS-B proposals "Geographic Applications of ERTS-B Imagery to Landscape Change" and "The Effect of Land-use and Other Watershed Characteristics Upon the Water Quality of Streams from the Watershed."

The general schematic diagram of a pattern recognition system is shown in Fig. 3. The function of the system is to yield a decision which identifies or classifies the input patterns. For example, these input patterns could be a series

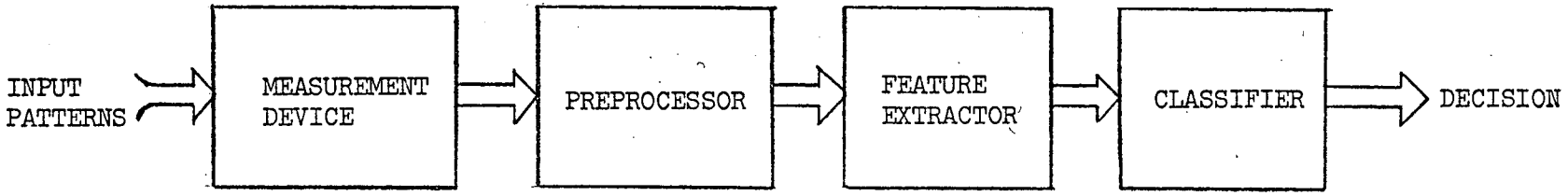


Fig. 3. General Form of a Pattern Recognition System

of multispectral images, and the required recognition task could be to identify regions in the images according to whether they are urban or rural.

The measurement device is generally considered to be the transducer which transforms the input patterns into a form suitable for machine manipulation. For example, in the case of film images, this device is a scanner which transforms an image into digital form.

The preprocessor performs the function of digital noise suppression plus any other functions associated with raw data preprocessing. In addition, it may perform specialized functions such as edge enhancement or line thinning.

The feature extractor is in charge of detecting features required for classification. Its function may be based on mathematical or statistical principles, but it very often simply consists of a set of ad hoc routines designed to perform a specific task.

The classifier is the decision maker. It uses the information provided by the feature extractor in order to make these decisions. Its structure may be based on mathematical, statistical, or syntactic principles as well as on ad hoc techniques. A combination of these approaches is not uncommon.

Our work in the application of pattern recognition to ERTS data will begin in the summer of 1973 in connection with our ERTS-A projects. It should be pointed out, however, that many of the functions of a pattern recognition system as discussed above are already operational in our system. All our measurement devices are being presently used. Many of the preprocessing routines used for image enhancement are also used for pattern recognition. This also holds true for feature extraction. For instance, histogram generation and boundary extraction are examples of feature extraction operations. The bulk of the work which remains to be done is in connection with

classification techniques. Our work in this area will be divided into the following principal categories:

- Mathematical
- Statistical
- Syntactic
- Ad hoc

The mathematical approach to classification is normally based on a distance function concept. Cluster-seeking techniques are of particular importance in this approach. These techniques attempt to find clusters in numerical data as a means of establishing measures of similarity. A software package developed at the Stanford Research Institute offers a very attractive approach to cluster seeking. This program, called ISODATA, is presently being implemented at the University of Tennessee in connection with the author's research on the application of pattern recognition to reactor noise analysis. It will soon be available for use in our ERTS effort as well.

Statistical classifiers are normally based on the so-called Bayes classification scheme. This work is well established and its application to ERTS data will present little difficulty. As a matter of fact, software packages for the implementation of Bayes classifiers are already operational on our IBM-360/65 system.

The syntactic approach to pattern recognition is considered by many to be one of the most promising approaches to this problem. The principal advantage of this relatively new approach is that it can handle pattern structures better than either the statistical or mathematical techniques. This is particularly important in image work where one is interested in detecting regions. Our efforts in this area are well under way. The author is presently supervising a Ph.D. dissertation in this area and we expect part of this work to be applied to

the ERTS program in connection with the classification of strip mining in the Tennessee Valley.

Based on the data rates with which we are being confronted, it is not difficult to conclude that we have no choice but to make use of present automatic data handling capabilities, and to intensify the research in areas related to this problem. It is safe to say that the success of a national earth resources program will be largely dependent on our ability to automatically process the information generated by this program.

2.3 ANTICIPATED RESULTS

The results expected of this investigation are improved processing techniques for ERTS data. Our experience with THEMIS and ERTS-A will serve as the base for new developments in the machine handling of these data. We expect to improve and implement the large computer programs described in the last section. Care is being taken to implement these programs in standard computer languages (FORTRAN IV and PL1) so that they will be available to a large group of users.

Because of the considerable amount of research in image enhancement techniques presently being conducted in the Electrical Engineering Department, we expect to make significant contributions in this field. One example of this is the Image Processing Laboratory previously mentioned. With the aid of other multidisciplinary groups in the University we are certain that this facility will solve many problems in the human aspects of enhancing and processing ERTS data by means of interactive computer data manipulation and display.

We are also expecting to make a real contribution in the field of automatic interpretation of ERTS imagery. As was previously mentioned, we feel that this is a problem of crucial importance in the ERTS program. Although it is realistic to

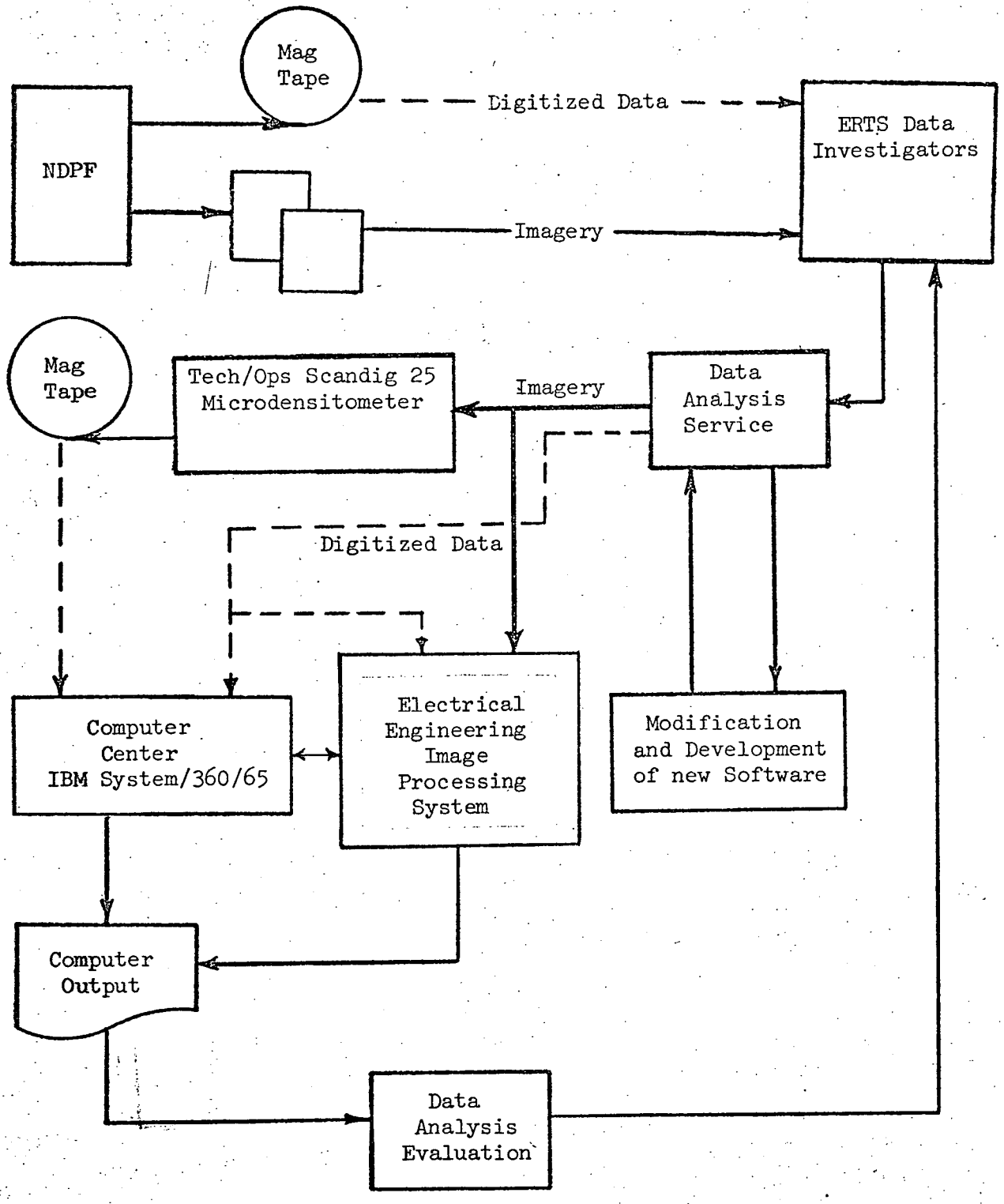


Fig. 4. Flow Diagram Showing the Handling and Processing of Data

accept that this is an extremely difficult problem, our approach will be to focus attention on specific problems related to our overall ERTS research program. We believe that in the forseeable future the state of the art is this area will dictate that automatic recognition of images be directed to specific tasks. Our background and equipment should prove more than sufficient to make significant advances in this area.

3.0 SUPPORTING BACK-UP DATA

3.1 DATA HANDLING PLAN

3.1.1 General - This project will utilize ERTS-B data in the form of film imagery as well as computer compatible tapes. The tapes will be processed both in an IBM 360/65 and in the image processing facility of the Electrical Engineering Department. The film imagery will undergo direct human as well as computer processing. The films can be transformed into digital tapes by scanning them with a high-resolution microdensitometer. For coarser processing, the image processing laboratory is equipped with a TV camera which can be used to scan the films and store the results on magnetic tape. Processing can then be carried out either on the IBM 360/65 or in the PDP-11 located in the image processing laboratory.

3.1.2 Processing - The flow chart shown in Fig. 4 represents the coordinated effort in data analysis and processing. As is indicated in the figure, the data is received from the National Data Processing Facility (NDPF) in either magnetic tape or film form. This data is then analyzed visually by the ERTS investigators. If computer processing is required, the data can follow one of two basic paths. One way to handle the

film data digitally is to digitize the film using the microdensitometer shown in Fig. 4. The output of this unit is a 256-gray-level image stored in magnetic tape. This tape can then be run in the IBM 360/65 using one of the software packages available for this type of processing. Some typical operations we are now able to carry out are density slicing, edge enhancement, histogram generation, and tonal digital outputs, as was mentioned in Section 2.2. The digitized data received from NDPF can, of course, be run directly on the IBM 360.

The second method to process the data is to use the Electrical Engineering Image Processing System shown in Fig. 4. This system is shown in more detail in Fig. 5. As shown in this figure, the system consists basically of a Digital Equipment Corp. (DEC) PDP-11 computer equipped with a 9-track computer compatible tape unit. The computer is also equipped with a TV camera for film input, monochrome and color TV monitors, and a scan converter which converts digital information into video output. The system will soon be capable of handling almost any processing which is presently being carried out in the IBM-360. In addition, however, the system has the capability of displaying the processed images in either the monochrome or color TV monitor. This capability is extremely powerful since it can be used on a semi-real time basis. One application, for example, is to scan a film image using the TV camera. The scanned image is stored in magnetic tape. This image is the enhanced and displayed in pseudo color via the scan converter and TV monitor. The color combinations can be changed almost instantaneously and the image then displayed again in order to highlight events of interest. In addition, it should be noted that the PDP-11 and IBM-360 are linked by means of the computer compatible tape unit. Any processing for which the PDP-11 proves inadequate can be carried out on the 360 and the results

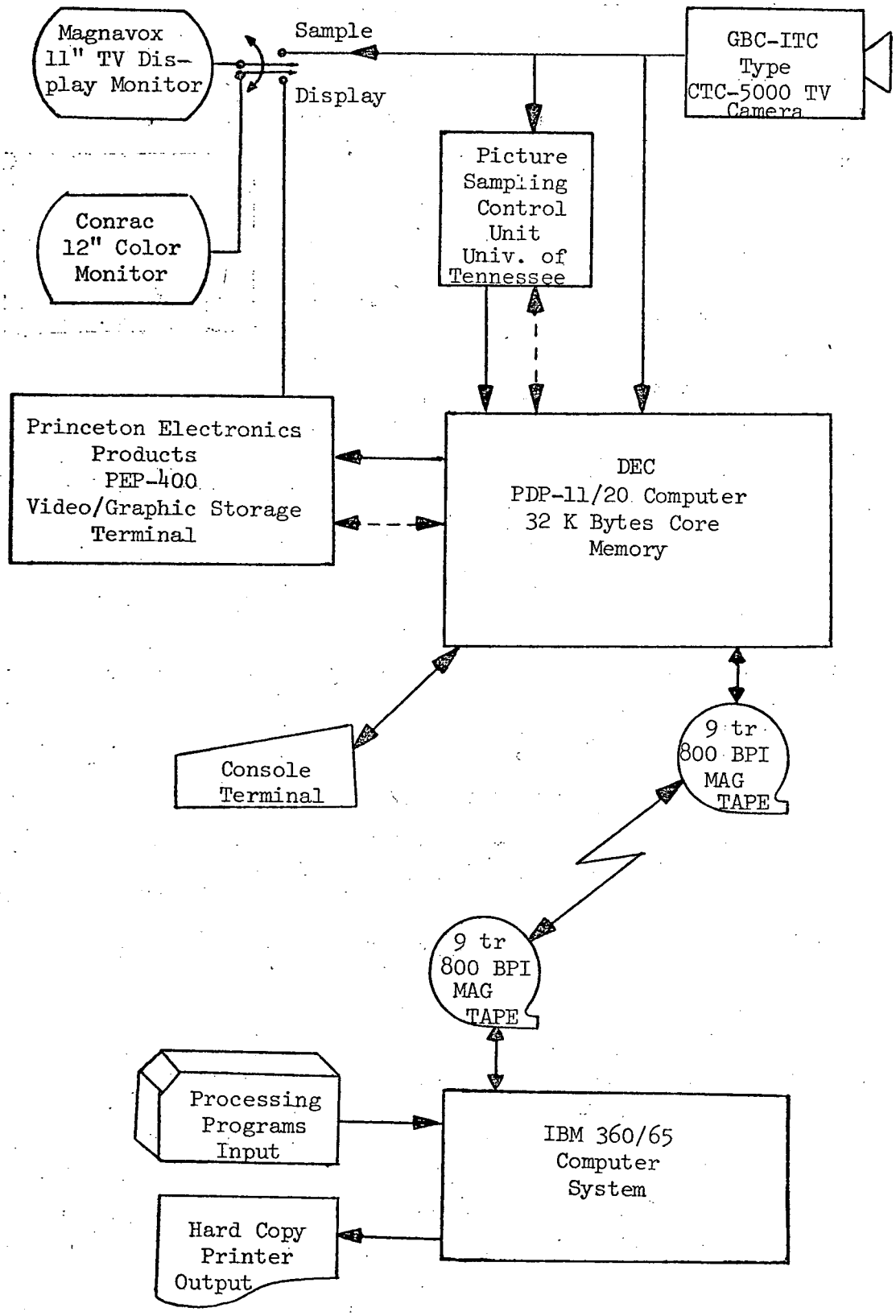


Fig. 5. Block Diagram of the University of Tennessee's Computer Image Processing and Recognition Laboratory

displayed on one of the monitors. A Polaroid photograph yields a quick hard copy of the results.

The specifications of the main components of the entire data processing facility are listed below.

Summary of Pertinent Specifications

A. The University of Tennessee Computing Center

The University of Tennessee is equipped with an IBM System/360/65 system. This system has 256K of fast storage and 256K of slow storage available for users. The basic system is complemented with two IBM 2780 high speed remote job card reader/printer terminals located at strategic points on the campus. One of these units is in the Electrical Engineering Department.

In addition, the University has approximately twelve 360 time sharing teletypes operating under CALL/360/OS. These units are particularly helpful for debugging subroutines. The System/360/65 operates under MVT, release 19.

B. The College of Engineering Microdensitometer Laboratory

TECH/OPS Scandig 25 Microdensitometer.

Density

Range	0-3D
Resolution	0.012D
Reproducibility	0.01D
Linearity	0.01D
No. of Increments	256

Sampling Lattice

x-direction (line separation along the axis of drum) 25-, 50-, and 100-microns

y-direction (sampling interval along the circumference of drum) 25-, 50-, and 100-microns

Scanning Aperture

Imaging Aperture 25-, 50- and 100-microns

Scanning Window

x-direction 0-175 mm adjustable in 1 mm increments

y-direction 0-125 mm adjustable in 1 mm increments

Sample Size

12.5 cm x 2.5 cm to 17.5 cm

Recording Speed

20,000 readings/second, FIXED

Output to Tape Unit

8-bit binary

Tape Unit: Kennedy Model 3110

Packing Density	800 bpi, 9-track, NRZI
Tape Speed	25 ips
Error Checks	CRCC, including LP and LRCC
Compatibility	IBM System/360 Compatible
Max Writing Rate	20 KHz
Max Tape Length	2400-ft

Spatial Resolution - Mechanical

x-direction	10 microns
y-direction	10 microns

C. <u>The Department of Electrical Engineering Image Processing Laboratory</u>

1. PDP-11/20 with 16 K, 16 bit word Read/Write 950 nanosecond cycle time memory with the following peripheral equipment:
   a. Four 11 bit bipolar A/D conversion channels;
   b. Three 12 bit bipolar D/A conversion channels;
   c. Extended arithmetic element permitting multiplication and division operations with 16 bit numbers, 32 bit products, 16 bit quotients and 32-bit dividends in 5 microseconds;

d. ASR-33 Teletype;

e. Device register interface that permits direct access to and from the CPU which is useful is the design of prototype interfaces;

f. 100 KHz crystal controlled programmable clock.

g. High speed paper tape and punch.

h. Industry compatible magnetic tape unit.

2. Camera - GBC Model CTC-5000 Closed Circuit Black and White Television Camera

a. Horizontal resolution at center $\geq$ 650 lines

b. Scanning standard 525 line, 2:1 interface

c. Vertical sweep 60 Hz
Horizontal sweep 15.75 kHz
Both crystal controlled synchronization

d. Sensitivity usable at 0.15 FC minimum on Vidicon Face Plate with automatic sensitivity control (5000:1)

e. Video output 1.4 V_{pp} (1.0 V_{pp} video only)
Composite video f_r = 0 to 8.5 MHz, > 40 dB peak to peak signal to rms noise Z_L = 75 Ω

f. Lens Mount - standard "C" mount

g. Lens - 25 mm F1.4 close-up (DH-1)

3. Scan Converter - Princeton Electronic Products, Inc. Model PEP-400R video/graphic storage terminal with 1M-800-HS Lithocon^R silicon storage tube DC video write amp, TTL master logic, standard 525 line 2:1 interlace sync

a. Resolution - 1400 TV line at center 1000 TV line at edge

b. Retention time - > 12 minutes (for decay to half of gray levels); > 4 wks with beam cut off

c. Gram Scale - 10 logarithmic shades, 32 linear shades

d. Video Out - 0-30 MHz 1V_{pp} minimum standard 525 line 2:1 interlace sync signals meeting EIA standards Z_{out} = 75Ω signal/noise 33 dB minimum peak signal to rms noise

e. Video Input - 0-30 MHz, $Z_{in} \approx$ 75Ω, 0-1.0 volts

f. Deflection - magnetic deflection (amp has 1.5 MHz bandwidth), full screen diagonal settling time 7μs.

g. Sweep Generator - used to generate video raster

h. Synchronization - oscillator phase locked to power line, set for 525 line, 2:1 interlace, H&V drive and composite sync outputs available

i. Focus - combination of electromagnetic and electrostatic with write focus correction and dynamic correction action

j. Analog Inputs - x and y, Z_{in} - 100Ω, $V_{in} \approx$ ± 0.75 volts full deflection, Z axis same as video input above

k. Graphics Blanking Control Lithocon^{R} Beam in x-y mode logic connector - provides for external control of scan converter operating mode

4. Standard 525 line, 2-1 interlace 11" diagonal Magnavox Black and White Monitor

   Compatible with above camera.

5. Conrac 12" diagonal color monitor Model 5001R12

   a. Resolution - limited only by color CRT. Linearity and geometry - no point on raster

deviates from its proper position by more than 2% of raster height.

b. Convergence - does not deviate more than 0.75% from picture height in a centrally located area bounded by a circle. The diameter of this circle is equal to picture height. Elsewhere, the deviation does not exceed 1.0% of picture height.

c. Phosphor colorimetry - similar to Conrac's controlled phosphors. Comparison of C.I.E. coordinates:

d.

	Conrac Standard 12" Single-Gun			
	x	y	x	y
Red	.630	.340	.645	.335
Green	.310	.600	.290	.600
Blue	.155	.070	.150	.065

e. Color Temperature - the range of RGB gain adjustments is sufficient to permit setting white color temperature to either 6500°K (factory setting) or 9300°K.

f. Color temperature stability - Color temperature of white does not change by more than one MPCD unit between monochrome and color input signals.

g. Interlace - Better than 90%.

h. Raster size regulation - Less than 1% change, 0% to 100% APL (Average Picture Level) at peak 20 fL luminance.

i. Black level stability - DC restorer maintains black level shift less than 1% of peak luminance from 10% to 90% APL.

j. Discernible shades of gray - 10, minimum.

k. Video
   Composite - Loop-through or switchable to internal 75 ohm termination. 1.0V p-p nominal (0.35V to 2.0V), sync negative.
   Noncomposite - 0.7V p-p nominal (0.25V to 1.4V) black negative.
   Return loss - Greater than 40 dB.

l. External sync - 4V p-p nominal (1V to 8V)

m. Video amplifier frequency response - Monochrome position ± 1 dB, to 5 MHz.

n. Video amplifier differential gain - Less than 5% for luminance range of 0 fL to 20 fL.

o. Aperture correction - A continuously adjustable front panel control provides up to 8 dB boost at 2.6 MHz.

p. Decoder accuracy - Decoder error less than 2.5°.

q. Chroma control - Provides continuous adjustment of chroma from nil to 6 dB above correct matrix.

r. Phase control - Provides continuous adjustment of subcarrier phase over the range of ± 25°.

s. Vertical retrace time - 1000μs maximum.

t. Horizontal retrace time - 10.0 μs maximum.

u. Low voltage regulation - Less than 1% change for variations from nominal line voltage of ± 10%.

v. High voltage regulation - Less than 2% change for 0% to 100% APL at 20 fL peak luminance.

3.1.3 Photo Reproductions - This investigation will not need photo reproduction services directly. A great deal of our ERTS-B data will be obtained directly from the other disciplines mentioned in Section 1.1.

3.1.4 Data Products - The data analysis system produces two basic forms of data products: visual and numerical. The visual products are monochrome and color photographs or tonal digital printouts. The numerical products are the results of calculations such as histograms. These results are often expressible in either tabular or graphical form.

3.2 DATA REQUIREMENTS

The data requirements for the interdisciplinary effort of the University of Tennessee have been outlined in the ERTS-B proposals mentioned in Section 1.1. It is anticipated that all the data for this investigation will be obtained from the other three groups involved in the effort. In this manner, our research will be directed toward the data of interest in the overall ERTS program of the University.

3.2.1 Product Requirement - As indicated in the multidisciplinary ERTS-B proposals mentioned in Section 1.1. None for this investigation.

3.2.2 DCS Requirement - Same as Section 3.2.1.

3.2.3 Government Aircraft Coverage Requirement - Same as Section 3.2.1.

3.2.4 Ground Truth Requirement - Same as Section 3.2.1.

4.0 KEY PERSONNEL

See Investigation Synopsis and Management Proposal, Part II.

REFERENCES

1. Vachon, R.I., Gonzalez, R.C., et. al., "ERISTAR, Earth Resources Information, Storage, Transformation and Retrieval System," NASA technical report CR-61392, Sept. 1972.

2. Bodenheimer, R.E., and Green, W.L., "Information Processing of Photographic Imagery," Proceedings of the 9th Annual IEEE Region III Convention, April, 1971, pp. 417-422.

3. Bodenheimer, R.E., and W.L. Green, "Digital Image Processing and Interpretation of Photographic Film Data," Proceedings of the 1972 IEEE Region III Conference, (April, 1972) pp. 417-422.

4. Bodenheimer, R.E., and W.L. Green, "Information Processing of Remote Sensing Signals," Task V Project THEMIS: Remote Sensor Utilization for Environmental System Studies, Period from November 15, 1969 to November 14, 1970, Second Annual Report Part I, Contract No. F19628-69-C-0116, pp. 65-80.

5. Bodenheimer, R.E., and W.L. Green, "Information Processing of Remote Sensing Signals," Task V Project THEMIS: Remote Sensor Utilization for Environmental System Studies, Period from November 15, 1970 to November 14, 1971, Third Annual Report Part I, Contract No. F19628-69-C-0116, pp. 46-60.

6. Bodenheimer, R.E., and W.L. Green "Information Processing of Remote Sensing Signals," Task V Project THEMIS: Remote Sensor Utilization for Environmental System Studies, Period from November 15, 1968 to November 14, 1972, Final Report, Contract No. F19628-69-C-0116.

7. Andrews, H.C., Tescher, A.G., and Kruger, R.P., "Image Processing by Digital Computer," IEEE Spectrum, July, 1972.

8. Oppenheim, A.V., Schafer, R.W., and Stockham, R.G., Jr., "Nonlinear Filtering of Multiplied and Convolved Signals," Proc. IEEE, Vol. 56, pp. 1264-1291, August, 1968.

9. "Remote Spectral Sensing in Agriculture," Annual Report--Vol. 4, Laboratory for Agricultural Remote Sensing (LARSYS), Agriculture Experiment Station, Purdue University, Lafayette, Indiana, 1970.

10. Rosenfeld, A., Picture Processing by Computer, Academic Press, 1969.

11. Tou, J.T. and Gonzalez, R.C., Principles of Pattern Recognition, textbook in preparation.

12. Gonzalez, R.C., "Syntactic Pattern Recognition - Introduction and Survey," Proceedings of the NEC, Vol. 27, October, 1972.

13. Gonzalez, R.C. and Thompson, D.D., "Minicomputer Implementation of an Image Processing System for Teaching and Research," Proceedings of the Computer Science Conference, Columbus, Ohio, February, 1973.

14. Gonzalez, R.C. and Thompson, D.D., "The Potential of Formal Language Theory in Adaptive Digital Filter Design for Image Enhancement," Proceedings of the 5th Annual Southeastern Symposium on System Theory, Raleigh, North Carolina, March, 1973.

PART II

MANAGEMENT PROPOSAL

1.0 BUSINESS MANAGEMENT ORGANIZATION AND PERSONNEL

The proposed research will be conducted and performed by the Electrical Engineering Department of The University of Tennessee, Knoxville, Tennessee. Research funds are handled and dispersed through the Office of the Treasurer, The University of Tennessee. Bookkeeping, audits, etc. are the responsibility of this office. All effort, decision-making and budgeting for carrying-out the proposed research is the responsibility of the Principal Investigator. The resume of the Principal Investigator may be found in Section 3.0, Part II of the Management Proposal.

2.0 RESOURCE REQUIREMENTS

The available resources to perform the task proposed by this research includes office and laboratory space, IBM System/360/65 Computer, Tech/Ops x-y scanning microdensitometer, image processing laboratory, and senior technical staff.

Approximately 1200 sq. ft. of office space in the Department of Electrical Engineering is available to the technical personnel for performing this research. This includes the Department of Electrical Engineering Image Processing Laboratory. In addition, there is the College of Engineering Microdensitometer Laboratory and The University of Tennessee Computer Center facility. The equipment resources available from these facilities are described in Section 2.1, Capital Equipment below. Both investigators have research experience in the ERTS-A Program. However, no equipment or facilities were acquired or purchased from

ERTS-A funds. All of these resources through this project will be available to the research groups described in Sections 1.0 and 1.2 of the Technical Proposal.

2.1 CAPITAL EQUIPMENT

Summary of Pertinent Specifications

A. The University of Tennessee Computing Center

The University of Tennessee is equipped with an IBM System/360/65 system. This system has 256K of fast storage and 256K of slow storage available for users. The basic system is complemented with two IBM 2780 high speed remote job card reader/printer terminals located at strategic points on the campus. One of these units is in the Electrical Engineering Department.

In addition, the University has approximately twelve 360 time sharing teletypes operating under CALL/360/OS. These units are particularly helpful for debugging subroutines. The System/360/65 operates under MVT, release 19.

B. The College of Engineering Microdensitometer Laboratory

TECH/OPS Scandig 25 Microdensitometer.

Density

Range	0-3D
Resolution	0.012D
Reproducibility	0.01D
Linearity	0.01D
No. of Increments	256

Sampling Lattice

x-direction (line separation along the axis of drum) 25-, 50-, and 100-microns

y-direction (sampling interval along the circumference of drum) 25-, 50-, and 100-microns

Scanning Aperture

Imaging Aperture 25-, 50- and 100-microns

Scanning Window

x-direction 0-175 mm adjustable in 1 mm increments

y-direction 0-125 mm adjustable in 1 mm increments

Sample Size

12.5 cm x 2.5 cm to 17.5 cm

Recording Speed

20,000 readings/second, FIXED

Output to Tape Unit

8-bit binary

Tape Unit: Kennedy Model 3110

Packing Density	800 bpi, 9-track, NRZI
Tape Speed	25 ips
Error Checks	CRCC, including LP and LRCC
Compatibility	IBM System/360 Compatible
Max Writing Rate	20 KHz
Max Tape Length	2400-ft

Spatial Resolution - Mechanical

x-direction	10 microns
y-direction	10 microns

C. <u>The Department of Electrical Engineering Image Processing Laboratory</u>

1. PDP-11/20 with 16 K, 16 bit word Read/Write 950 nanosecond cycle time memory with the following peripheral equipment:
   a. Four 11 bit bipolar A/D conversion channels;
   b. Three 12 bit bipolar D/A conversion channels;
   c. Extended arithmetic element permitting multiplication and division operations with 16 bit numbers, 32 bit products, 16 bit quotients and 32-bit dividends in 5 microseconds;

d. ASR-33 Teletype;

e. Device register interface that permits direct access to and from the CPU which is useful is the design of prototype interfaces;

f. 100 KHz crystal controlled programmable clock.

g. High speed paper tape and punch.

h. Industry compatible magnetic tape unit.

2. Camera - GBC Model CTC-5000 Closed Circuit Black and White Television Camera

a. Horizontal resolution at center $\geq$ 650 lines

b. Scanning standard 525 line, 2:1 interface

c. Vertical sweep 60 Hz
Horizontal sweep 15.75 kHz
Both crystal controlled synchronization

d. Sensitivity usable at 0.15 FC minimum on Vidicon Face Plate with automatic sensitivity control (5000:1)

e. Video output 1.4 V_{pp} (1.0 V_{pp} video only)
Composite video f_r = 0 to 8.5 MHz, > 40 dB peak to peak signal to rms noise Z_L = 75 Ω

f. Lens Mount - standard "C" mount

g. Lens - 25 mm F1.4 close-up (DH-1)

3. Scan Converter - Princeton Electronic Products, Inc. Model PEP-400R video/graphic storage terminal with 1M-800-HS Lithocon^R silicon storage tube DC video write amp, TTL master logic, standard 525 line 2:1 interlace sync

a. Resolution - 1400 TV line at center 1000 TV line at edge

b. Retention time - > 12 minutes (for decay to half of gray levels); > 4 wks with beam cut off

c. Gram Scale - 10 logarithmic shades, 32 linear shades

d. Video Out - 0-30 MHz $1V_{pp}$ minimum standard 525 line 2:1 interlace sync signals meeting EIA standards Z_{out} = 75Ω signal/noise 33 dB minimum peak signal to rms noise

e. Video Input - 0-30 MHz, $Z_{in} \approx 75\Omega$, 0-1.0 volts

f. Deflection - magnetic deflection (amp has 1.5 MHz bandwidth), full screen diagonal settling time 7μs.

g. Sweep Generator - used to generate video raster

h. Synchronization - oscillator phase locked to power line, set for 525 line, 2:1 interlace, H&V drive and composite sync outputs available

i. Focus - combination of electromagnetic and electrostatic with write focus correction and dynamic correction action

j. Analog Inputs - x and y, Z_{in} - 100Ω, $V_{in} \approx \pm$ 0.75 volts full deflection, Z axis same as video input above

k. Graphics Blanking Control Lithocon^{R} Beam in x-y mode logic connector - provides for external control of scan converter operating mode

4. Standard 525 line, 2-1 interlace 11" diagonal Magnavox Black and White Monitor
   Compatible with above camera.

5. Conrac 12" diagonal color monitor Model 5001R12
   a. Resolution - limited only by color CRT. Linearity and geometry - no point on raster

deviates from its proper position by more than 2% of raster height.

b. Convergence - does not deviate more than 0.75% from picture height in a centrally located area bounded by a circle. The diameter of this circle is equal to picture height. Elsewhere, the deviation does not exceed 1.0% of picture height.

c. Phosphor colorimetry - similar to Conrac's controlled phosphors. Comparison of C.I.E. coordinates:

d.

	Conrac Standard 12" Single-Gun			
	x	y	x	y
Red	.630	.340	.645	.335
Green	.310	.600	.290	.600
Blue	.155	.070	.150	.065

e. Color Temperature - the range of RGB gain adjustments is sufficient to permit setting white color temperature to either 6500°K (factory setting) or 9300°K.

f. Color temperature stability - Color temperature of white does not change by more than one MPCD unit between monochrome and color input signals.

g. Interlace - Better than 90%.

h. Raster size regulation - Less than 1% change, 0% to 100% APL (Average Picture Level) at peak 20 fL luminance.

i. Black level stability - DC restorer maintains black level shift less than 1% of peak luminance from 10% to 90% APL.

j. Discernible shades of gray - 10, minimum.

k. Video
   Composite - Loop-through or switchable to internal 75 ohm termination. 1.0V p-p nominal (0.35V to 2.0V), sync negative.
   Noncomposite - 0.7V p-p nominal (0.25V to 1.4V) black negative.
   Return loss - Greater than 40 dB.

l. External sync - 4V p-p nominal (1V to 8V)

m. Video amplifier frequency response - Monochrome position ± 1 dB, to 5 MHz.

n. Video amplifier differential gain - Less than 5% for luminance range of 0 fL to 20 fL.

o. Aperture correction - A continuously adjustable front panel control provides up to 8 dB boost at 2.6 MHz.

p. Decoder accuracy - Decoder error less than 2.5°.

q. Chroma control - Provides continuous adjustment of chroma from nil to 6 dB above correct matrix.

r. Phase control - Provides continuous adjustment of subcarrier phase over the range of $\pm 25^{\circ}$.

s. Vertical retrace time - 1000μs maximum.

t. Horizontal retrace time - 10.0 μs maximum.

u. Low voltage regulation - Less than 1% change for variations from nominal line voltage of ± 10%.

v. High voltage regulation - Less than 2% change for 0% to 100% APL at 20 fL peak luminance.

2.2 DCS EQUIPMENT

No DCS Equipment is required in the proposed research. However, such requests may have been generated by those

groups described in Sections 1.1 and 1.2 of the Technical Proposal.

2.3 GOVERNMENT FURNISHED EQUIPMENT

No GFE requirements are anticipated.

2.4 AUTOMATIC DATA PROCESSING EQUIPMENT

No procurement of automatic data processing equipment is required for this project.

3.0 PERSONNEL

Proposed personnel according to professional classification are:

Job Description	Number
Engineers	2
Students	1 Ph.D. Research Asst.
	1 Graduate Research Asst.
Programmer (Hourly-Help)	1 Undergraduate Research Asst.
Clerical	1 Part-time

The following pages describe the education and experience of the Project Principal Investigator and the Co-Investigator. Note that Dr. Bodenheimer has prior remote sensing experience with The University of Tennessee Project THEMIS: Remote Sensor Utilization for Environmental Systems Studies Research Program. Both Dr. Gonzalez and Dr. Bodenheimer (UN 654) have participated in the ERTS-A Program.

NAS5-21875 "ERTS-A Imagery Interpretation Techniques in the Tennessee Valley."

RESUMES

R. C. Gonzalez
Electrical Engineering Department
University of Tennessee
Knoxville, Tennessee 37916

EDUCATION

B.S., Electrical Engineering, 1965, University of Miami

M.E., Electrical Engineering, 1967, University of Florida, Gainesville

Ph.D., Electrical Engineering, 1970, University of Florida, (Dissertation: "Pattern Recognition Via Topological Feature Extraction." Advisor: Dr. J. T. Tou.

PROFESSIONAL SOCIETIES

Institute of Electrical and Electronics Engineers
American Society for Engineering Education
Pattern Recognition Society

PROFESSIONAL EXPERIENCE

1970-present — Assistant Professor of Electrical Engineering and Computer Science
The University of Tennessee, Knoxville.

1. Member of the Electrical Engineering Computer Group.
2. Teaching and research focused primarily in the area of computer and information science.
3. Responsible for the introduction of several courses in pattern recognition, artificial intelligence, and image processing by computer at the graduate and undergraduate levels.

Summer 1972 — Faculty Research Fellow, NASA/ASEE Program, Marshall Space Flight Center, Huntsville, Alabama.
Design of an earth resources information management system.

April 1972-present — Consultant, Oak Ridge National Laboratory.

1967-1970 Graduate Research Assistant, Center for Informatics Research, University of Florida, Gainesville.
1. Research in the area of pattern recognition, information retrieval, and artificial intelligence.
2. Development of a software package for optical character recognition.
3. Programming for the Center, Languages used: Fortran IV, PL1, SNOBOL IV, IBM-360, and DEC PDP-8 Assembly Language.

1966-1967 Teaching Assistant of Electrical Engineering, The University of Florida.
1. Taught and monitored computer, communications, and circuits laboratories.
2. Development of several new approaches to laboratory experiments and procedures.

1965-1966 Communications systems engineer, General Telephone and Electronics.
1. Design of voice communication links.
2. Design of digital communication networks.

RESEARCH ACTIVITIES

General area of interest: Computer and Information Science.

Areas of Specific research activities: pattern recognition, artificial intelligence, computer simulation, image processing by computer.

Recent work: Feature extraction algorithms, optimal pattern classification algorithms, application of functional approximation concepts to highway research, design of a pattern recognition system for automatic EEG sleep-state identification, application of image processing techniques to map reading and interpretation, syntactic pattern recognition, interpretation of ERTS-A satellite images, nuclear reactor noise analysis, information analysis related to earth resources.

PUBLICATIONS

BOOKS:

Principles of Pattern Recognition, coauthored with J. T. Tou. Due to appear in late 1973.

ARTICLES AND REPORTS:

Gonzalez, R.C. and Tou, J.T., "Some Results in Minimum-Entropy Feature Extraction," IEEE Convention Record, Region III, November, 1967

Gonzalez, R.C., "Pattern Recognition Via Topological Feature Extraction," Ph.D. Dissertation, The University of Florida, 1970.

Tou, J.T. and Gonzalez, R.C. "A New Approach to Automatic Recognition of Handwritten Characters," Technical Report No. 70-101, Center for Informatics Research, University of Florida, Gainesville, 1970.

Gonzalez, R.C. and Tou, J.T., "Automatic Recognition of Handwritten Characters by Topological Feature Extraction," Proceedings of the Two-Dimensional Digital Signal Processing Conference, University of Missouri, Columbia, October, 1971.

Bishop, A.O., Jr. and Gonzalez, R.C., "Digital Filtering as an Intermediate Step in the Computerized Analysis of Electrocardiograms," Proceedings of the 24th Annual Conference of Engineering in Medicine and Biology, Las Vegas, Nevada, 1971.

Warmack, R.E. and Gonzalez, R.C., "Minimum-Error Pattern Recognition in Supervised Learning Environments," IEEE Convention Record, Region III, April, 1972.

Gonzalez, R.C., Lane, M.C., Bishop, A.O., Jr., and Wilson, W.P., "Some Results in Automatic Sleep-State Classification," Proceedings of the Fourth Southeastern Symposium on System Theory, April, 1972.

Tou, J.T. and Gonzalez, R.C., "Pattern Recognition Via Topological Feature Extraction and Multilevel Decision," International Journal of Computer and Information Science, Vol. 1, No. 1, May, 1972.

Tou, J.T. and Gonzalez, R.C., "Recognition of Handwritten Characters by Topological Feature Extraction and Multilevel Categorization," IEEE Transactions on Computers, Vol. 1, c-21, No. 7, July, 1972.

Gonzalez, R.C. and Tou, J.T., "A Geometrical Approach to the Solution of Linear Inequalities," to appear.

Gonzalez, R.C., "Syntactic Approach to Pattern Recognition," Proceedings of the Conference on Computer Image Processing and Recognition, Vol. 2, University of Missouri, Columbia, August, 1972.

Vachon, R.I., Gonzalez, R.C., et. al., "ERISTAR, Earth Resources Information, Storage, Transformation, and Retrieval System," NASA technical report CR-61392, Sept., 1972.

Gonzalez, R.C., "Syntactic Pattern Recognition - Introduction and Survey," Proceedings of the NEC, Vol. 27, October, 1972.

Warmack, R.E. and Gonzalez, R.C., "An Algorithm for the Optimal Solution of Linear Inequalities and its Application to Pattern Recognition," to appear in IEEE Transactions on Computers.

Gonzalez, R.C. and Thompson, D.D., "Minicomputer Implementation of an Image Processing System for Teaching and Research," Proceedings of the Computer Science Conference, Columbus, Ohio, Feb., 1973.

Gonzalez, R.C. and Thompson, D.D., "The Potential of Formal Language Theory in Adaptive Digital Filter Design for Image Enhancement," Proceedings of the 5th Annual Southeastern Symposium on System Theory, Raleigh, North Carolina, March, 1973.

R. E. Bodenheimer
Electrical Engineering Department
University of Tennessee
Knoxville, Tennessee 37916

EDUCATION:

B.S.E.E. The University of Tennessee, June, 1956
M.S.E.E. The University of Tennessee, December, 1958
Ph.D Northwestern University, August, 1965

PROFESSIONAL SOCIETIES

Institute of Electrical and Electronics Engineers (IEEE)
American Society for Engineering Education (ASEE)

PROFESSIONAL EXPERIENCE

Employer - The University of Tennessee
Period - Fall 1964 to Present
Position - Associate Professor of Electrical Engineering

Employer - ORTEC, Inc. Oak Ridge
Period - February 1968 to Present
Position - Consultant

Employer - ORTEC, Inc. Oak Ridge
Period - Summers of 1968, 1969, 1970, 1971, 1972
Position - Engineer in Research Development - Life Science Group

Employer - Foote Mineral Company - Electromanganese Division
Period - January 1966 to December 1966
Position - Consultant

Employer - Northwestern University
Period - Summer 1962 to Fall 1964
Position - Instructor of Electrical Engineering

Employer - The University of Tennessee
Period - Fall 1959 to Fall 1961
Position - Assistant Professor of Electrical Engineering

Employer - The University of Tennessee
Period - Summer 1957 to Fall 1959
Position - Instructor of Electrical Engineering

Employer - Knoxville Utilities Board
Period - Summer 1956
Position - Engineer in Relay/Test Division

RESEARCH ACTIVITIES

General area of interest: Digital Systems Design

Areas of specific research activities: ERTS-1 Imagery Interpretation Techniques in the Tennessee Valley, Task V Information Processing of Remote Sensing Signals - Project THEMIS for Remote Sensing of the Environment, Development of a Digital Logic Laboratory - Instructional Scientific Equipment Program NAS, Measurement of a Physiological Performance Index for a Man in Space.

Recent work: computer design, digital instrumentation for neurophysiological, physiological and biomedical

applications, and data and information processing with applications to the field of remote sensing.

PUBLICATIONS

ARTICLES AND REPORTS:

Bodenheimer, R.E., and L.W. Hill, "Worst-Case Differential Linearity Expressions for Four Types of Digital to Analog Converters," Accepted for presentation at the 1973 IEEE - SOUTHEAST-CON, and published in Conference Record, Louisville, Kentucky, (May, 1973).

Bodenheimer, R.E., and W.L. Green, "Digital Image Processing and Interpretation of Photographic Film Data," Proceedings of the 1972 IEEE Region III Conference, (April, 1972) pp. M4-1 - M4-5.

Bodenheimer, R.E., and W.L. Green, "Information Processing of Photographic Imagery," Proceedings of the 9th Annual (1971) IEEE Region III Convention, (April, 1971) pp. 417-422.

Bodenheimer, R.E., "Analysis and Design of Pulse frequency Modulated Control Systems," Ph.D. Dissertation, Northwestern University, Evanston, Illinois, 1965.

Bodenheimer, R.E., H.P. Neff, and J.D. Tillman, "A Self-Phasing Circuit Receiving Antenna Array," District Conference Paper, A.I.E.E. South Central District Meeting, Memphis, Tennessee 1963, Paper No. DP 62-543.

Bodenheimer, R.E., "Computation of Antenna Radiation Patterns Using a Digital Computer," Academy of Science, Annual Meeting, Knoxville, Tennessee 1960.

Bodenheimer, R.E., "Mutual Coupling Between Loudspeakers," M.S. Thesis, The University of Tennessee, Knoxville, Tennessee, 1958.

Bodenheimer, R.E., and W.L. Green, "Information Processing of Remote Sensing Signals," Task V Project THEMIS: Remote Sensor Utilization for Environmental System Studies, Period from November 15, 1969 to November 14, 1970, Second Annual Report Part I, Contract No. F19628-69-C-0116, pp. 65-80.

Bodenheimer, R.E., and W.L. Green, "Information Processing of Remote Sensing Signals," Task V Project THEMIS: Remote Sensor Utilization for Environmental System Studies, Period from November 15, 1970 to November 14, 1971, Third Annual Report Part I, Contract No. F19628-69-C-0116, pp. 46-60.

Bodenheimer, R.E., and W.L. Green "Information Processing of Remote Sensing Signals," Task V Project THEMIS: Remote Sensor Utilization for Environmental System Studies, Period from November 15, 1968 to November 14, 1972, Final Report, Contract No. F19628-69-C0116.

4.0 FUNDING

Cost estimates for performing the proposed work, including direct labor and salaries, travel, computer time, equipment, miscellaneous, overhead, fringe benefits, etc. are itemized in Part III in accordance with suggested format.

4.1 OVERALL COST

The overall cost for performing the proposed research is $ 55,663.00. This represents 100% of the overall investigation cost for which government support is required. This does not reflect the resources which are already available to the proposal as described in Section 2.0 of the Management Proposal.

4.2 FEDERAL GOVERNMENT COST

All funds are being requested from NASA.

4.3 OTHER SOURCES

No other sources of funds are currently being pursued.

5.0 AIRCRAFT FLIGHTS

No aircraft flights are required in the proposed research. However, data may be processed which was generated by aircraft flights initiated by those groups described in Section 1.1 and 1.2 of the Technical Proposal.

6.0 CONTRACTUAL REQUIREMENTS

Article I - Scope of Work

The Contractor shall provide all personnel, services and facilities necessary to conduct an investigation with the data received from the Earth Resources Technology Satellite, Mission B (ERTS-B). The investigation shall be performed in accordance with the approach, intent and objectives specified in the Contractor's Proposal titled "ERTS-B Imagery Interpretation Techniques in the Tennessee Valley."

Phase I - Data Analysis Preparation

This phase is applicable to this contract.

The Contractor shall make all preparations necessary to establish within 30 days after execution of this contract a state of readiness to receive, process and analyze the ERTS-B data. Typical preparations shall include, but not be limited to equipment setup acquiring ground truth, test runs using simulated data, as available, photographic analysis, development of computer software, literature search and survey, information feedback to the project office regarding data quality, generation of outline of Data Processing Plan, etc.

Should the Contractor require precision processed data covering ground areas outside the limits of the United States, the Contractor shall be responsible for obtaining the required ground control point data including the foreign maps required to facilitate data processing by NDPF.

Phase II - Preliminary Data Analysis

The Contractor shall evaluate the first 2 months of ERTS-B and all available ground truth data and refine data reduction and analysis techniques, including any results developed in Phase I above, to reassess the validity of proposed objectives with actual flight and ground truth data in hand and to produce and report preliminary results where feasible. This phase will begin upon receipt of the first processed

ERTS-B data or substitutional data supplied in lieu thereof, and shall include the following activities:

a) Process the first two months of data received from the operation of the ERTS-B spacecraft and/or supplementary aircraft data as applicable.

b) Evaluate and, if necessary, revise or modify data processing and/or analysis procedures to assure compatibility with initial spacecraft data received. Revise ERTS-B and ground truth data requirements, as necessary, to achieve the proposed objectives. In particular, requirements for aircraft data to be acquired with NASA aircraft are to be reviewed as to their significance to the objectives of the investigation. Requirements for aircraft data vital to the success of the investigation are to be detailed in the data analysis plan to fully specify the test site, the types(s) of data required and the date(s) that the data are required for the investigation to proceed without interruption. Feasible alternatives to acquiring the data by methods other than the NASA aircraft may be presented for review and approval.

c) Prepare and submit to the Contracting Officer, or his duly designated representative, for approval, a Data Analysis Plan 3 months after receipt of first ERTS data. This document shall contain a detailed description of the planned schedule and data analysis effort for the remainder of the investigation. It shall also clearly specify any change in ERTS-B or ground truth data requirements and cost required to complete the proposed investigation. The Data Analysis Plan shall be accompanied by such supporting technical and cost evidence as required to explain and support the change(s). This plan is to be separate and distinct from, and not a part of, or in place of, the normal contractual reporting required by this contract. In the event that the data analysis plan remains as proposed, and no significant changes are required as a result of the initial two months of data, a simple letter

submission stating there are no changes in the plan will be acceptable. However, significant changes to the Data Analysis plans are to be submitted for approval as specified herein.

Phase III - Continuing Data Analysis

Work under this phase will begin upon receipt of the Government Contracting Officer's written approval of the Data Analysis Plan generated under Phase II above and continue for 15 months. This effort shall include the following activities:

a) Process and analyze ERTS-B (as defined in Article III) and ground truth data.

b) Revise and review, or evaluate and if necessary modify data processing and analysis procedures (such as techniques for extracting thematic information from imagery, digital computer programs, etc.) as required to achieve the proposed task objectives.

c) Publish results of this continuing data analysis as soon as practicable by the most appropriate method.

d) Publish a final report which shall include a discussion of the statistical validity and accuracy of the results and conclusions derived from the data analysis including a statistical error analysis, where applicable.

Article II - Deliverable Documentation

The Contractor shall prepare and submit the following documentation:

Item 1 - Five (5) copies of the Data Analysis Plan as specified in Phase II(c) of Article I shall be completed and delivered within three (3) calendar months after receipt of the first ERTS-B data.

Item 2 - Six (6) copies of all published reports, preprints, in-house reports, abstracts of talks, thesis, etc., resulting from the effort performed under this contract shall be submitted as soon as available.

Item 3 - Six (6) copies of Type I Progress Reports shall be prepared and submitted on two month intervals. The reports are due within ten days after the end of the period being reported. The first period shall end two months after date of contract. This report may be in letter format and shall contain as a minimum the following:

a. Title of the Investigation with ERTS-B proposal number.

b. GSFC Identification Number of the Principal Investigator.

c. A statement and explanation of any problems that are impeding the progress of the investigation.

d. A discussion of the accomplishments during the reporting period and those planned for the next reporting period.

e. A separate discussion of significant results and their relationship to practical applications or operational problems including estimates of the cost benefits of any significant results.

f. A listing of published articles, and/or papers, pre-prints, in-house reports, abstracts of talks, (if any), that were released during the reporting period.

g. Recommendations concerning practical changes in operations, additional investigative effort, correlation of effort and/or results as related to a maximum utilization of the ERTS system.

h. A list by date of any changes in standing order forms.

i. ERTS Image Descriptor Forms (Exhibit C attached hereto) as required by Article VII.

j. A listing by date of any Data Request Forms (for retrospective data) submitted to GSFC/NDPF during the reported period.

k. Other information specified in Paragraph 3.1 of Specification S-250-P-1C to the extent it is not covered above.

Item 4 - Six (6) copies of Type II Progress Reports shall be submitted every six months for the effort performed on the preceding six months (or portion thereof in the beginning of the contract) for the life of the contract. The reports are due within 20 days after the end of the period being reported. The first reporting period shall end six months after date of contract. No Type I Progress Report need be submitted for the Type I Report period immediately preceding the submission of the Type II Report. However, the Type II Report shall contain the progress for that period as well as summary of the six months progress.

Item 5 - Eight (8) copies of a Type III Final Report. One draft copy shall be submitted to the Contracting Office for review and approval within 30 days after the completion of Phase III. The Government shall complete a review of the draft and notify the Contractor of any required changes within 30 days after receipt of the draft. Eight copies of the Final Report shall be submitted within 30 days after receipt of the Contracting Officer's approval of the draft report. No Type II Report need be submitted for the six month period, or fraction thereof, between the last Type II Report and the Final Report.

Note: Items 3, 4 and 5 above shall be prepared in accordance with the requirements of GSFC Specification S-250-P-1C, March 1972, titled "Contractor-Prepared Monthly, periodic and Final Reports."

Item 6 - The Contractor shall submit four (4) copies of the following Financial Management Reports:

(Appropriate requirements will be incorporated into all cost reimbursable contracts.)

Article III - Definition of ERTS-B Data

For purposes of this contract, Earth Resources Technology Satellite Mission B (ERTS-B) data shall be defined as follows:

1) In flight data telemetered to earth from on-board sensors or aircraft imagery data supplied in lieu thereof and as requested in the above-cited proposal and/or amendments thereto.

2) Any product items (as listed in Figure 3-1 of the ERTS Users Handbook) produced by the NASA Data Processing Facility (NDPF) and either distributed or made available to the investigator upon formal request. Initial Standing Order data requirements for the investigator are specified in Exhibit B attached hereto. Requests for changes to the Standing Order data requirements will be submitted to the Technical Officer for approval.

3) Data from the investigators Data Collection Platform(s) (DCP), if applicable and specified in Exhibit D attached hereto.

4) Aircraft underflight imagery data.

Article IV - Government Furnished Property

Pursuant to Clause 4 of this contract the Government shall furnish for performance of the work required under provisions of this contract, the following items:

1) ERTS-B data from on-board sensors or aircraft imagery data supplied in lieu thereof furnished in imagery form or computer compatible magnetic tape. Location of scenes, frequency of coverage and quantity of initial Standing Order data shall be in accordance with the investigator's stated data requirements as shown in Exhibit B attached hereto.

2) Data Collection System data on computer listings, punched card or magnetic tape, as stated in Exhibit D attached hereto.

3) Data user's service items, when produced by NDPF and requested through procedures indicated in Section 4 of the ERTS Data Users Handbook.

4) To the extent indicated in Exhibit D, the Government (NASA) shall provide the Data Collection Platform(s), Test Set, Technical Users Manual, initial issue of basic Spare Parts and maintenance consultation as required.

The Investigator shall be responsible for providing Sensors, Power Supply, Interface Electronics, Installation, sheltering as required, maintenance oepration, and spare parts required beyond the initial issue.

Installation shall be accomplished and Operation for the purpose proposed shall commence within 90 days following delivery to the Investigator.

5) Aircraft underflight imagery data, as revised and/or updated, if applicable. Exhibit F indicates the preferred aircraft underflight coverage. If, due to scheduling problems, weather, or any other contingency, this coverage requirement cannot be supplied by NASA, NASA reserves the option of selecting alternatives.

6) Other NASA approved services and/or equipment, if any, as listed in Exhibit E hereto.

Article V - Advance Agreements

a) In the event of failure or non-nominal performance of key elements of the ERTS system, or the attainment of non-nominal orbit, the Government (NASA) will review each investigative effort in light of the then total systems capabilities and the resulting impact on the proposed investigation. Accordingly, no expenditure of funds for Phase III will be made without the Contracting Officer's written approval of the Data Processing Plan and authorization to proceed with Phase III activities.

b) Further, where correlative data (e.g., aircraft, ground truth, etc.) is required in the timely performance of this contract and the Contractor is dependent upon a third party other than NASA/GSFC to supply such data or services to acquire same, the Contractor shall be responsible for making all necessary contractual arrangements between the Contractor and subcontractor and a copy of the final agreement shall be furnished to the Contracting Officer, prior to starting work on Phase III of this contract.

c) In the event of a conflict in scheduled operations, including use of NASA aircraft, a priority determination on data acquisition and distribution will be made by the Technical Officer.

Article VI - Delivery and Archiving of Reduced Data

Pending the establishment of a Government facility dedicated to the archiving of reduced ERTS-B data, the Contractor shall make provision for storing and safekeeping such data for a period not to exceed one (1) year after completion of the effort required under the contract.

The Contractor shall reproduce and distribute ERTS Data as directed in writing by the Contracting Officer. Reimbursement for complying with such requests shall be in accordance with the provisions of the Data Requirements Clause of this contract.

Article VII - Data Bank

a) The NDPF information system has been established to accept and record descriptors for individual scenes, which will be maintained in the Data Bank and used to support queries from individual investigators. In addition, the descriptors will be cumulatively compiled, printed and distributed in the form of a catalog. Since NDPF does not perform any content analysis of images, this service is largely dependent on information input from the investigators.

Accordingly, the Contractor agrees to furnish to NDPF such information on Exhibit C which adequately describes the content of the scenes contained in his analysis and within his area of expertise. (See ERTS Users Handbook for glossary of terms).

b) Any anticipated delay in scheduled completion of the work herein agreed to and resulting directly from untimely availability of required data, shall be immediately brought to the attention of the Contracting Officer in writing, presenting all facts relevant to the case at hand.

Article VIII - Shipment

Shipment of the items called for herein shall be FOB destination and shall be shipped "all transportation cost prepaid" to NASA/GSFC as follows:

A) Item 1 of Article II shall be delivered to:

1 copy to ERTS Contracting Officer
Code 245, GSFC
Greenbelt, Maryland 20771

1 copy to ERTS Technical Officer
Code 430, GSFC
Greenbelt, Maryland 20771

1 copy to Master File
Code 430, GSFC
Greenbelt, Maryland 20771

1 copy to ERTS Project Scientist
Code 650, GSFC
Greenbelt, Maryland 20771

1 copy to ERTS Scientific Monitor
Code 650, GSFC
Greenbelt, Maryland 20771

B) Items 2, 3 and 4 of Article II shall be delivered to:

5 copies as specified for Item 1 above

1 copy to NASA Scientific and Technical Facility
Attention: ERTS Resources
P. O. Box 33
College Park, Maryland 20740

C) Item 5 of Article II shall be delivered to:

1 copy to Technical Information Division
Code 250, GSFC
Greenbelt, Maryland 20771

3 copies to ERTS Technical Officer
Code 430, GSFC
Greenbelt, Maryland 20771

1 copy to ERTS Program Manager
Code ER, NASA Headquarters
Washington, D.C. 20546

1 copy to ERTS Project Scientist
Code 650, GSFC
Greenbelt, Maryland 20771

1 copy to ERTS Scientific Monitor
Code 650, GSFC
Greenbelt, Maryland 20771

1 copy to ERTS Contracting Officer
Code 245, GSFC
Greenbelt, Maryland 20771

D) Item 6 (applicable to Cost Reimbursable Contracts only) of Article II shall be delivered to:

1 copy to ERTS Contracting Officer
Code 245, GSFC
Greenbelt, Maryland 20771

1 copy to ERTS Technical Officer
Code 430, GSFC
Greenbelt, Maryland 20771

1 copy to ERTS Business Representative
Code 430, GSFC
Greenbelt, Maryland 20771

1 copy to Automated 533 System
Code 264, GSFC
Greenbelt, Maryland 20771

Article IX - Data Use and Release Restrictions

a) The Contractor shall not use for other than governmental purposes, nor release, nor publish, any analysis/findings

or techniques developed under this contract, or any information derived therefrom, until such analysis/findings or techniques have been reported to the Government in the manner prescribed by this contract and the Contractor has been informed by the Government in writing that such reported analysis/findings or techniques have been made available to the general public.

b) If it is necessary in fulfilling the contract requirements that the Contractor release or disclose to others said analysis/findings or techniques, or any information derived therefrom, prior to being advised by the Government that such has been made available to the general public, the Contractor shall, before such release or disclosure, obtain a written agreement from the recipient to abide by the foregoing release and use restrictions.

Article X - Key Personnel and Facilities

Pursuant to Clause No. 127 (Key Personnel and Facilities), the following individual(s) and/or facilities are considered to be essential to the work being performed hereunder:

R.C. Gonzalez

R.E. Bodenheimer

*The Data Use and Release Restrictions detailed herein are those presently in effect for ERTS-A. It is contemplated that there will be changes in these provisions for ERTS-B when policy decisions now in process at NASA Headquarters are made.

Article XI - Disposition of Government Property

a) All magnetic tapes furnished by the Government (NASA), whether they contain data or not, shall remain the property of the Government. The Contractor shall be responsible for maintaining an accurate record of the quantity of such tapes furnished him, and shall return same no later than six (6) months following completion of the investigation or whenever the data contained thereon has served its useful

purpose and is no longer required by the Investigator. Return shipment shall be on Government Bill of Lading addressed to:

Goddard Space Flight Center
Greenbelt, Maryland 20771
Attention: Code 563 (NDPF)

b) The Data Collection Platforms, Test Sets and Technical Users Manuals and residual basic spare parts shall be returned to NASA/GSFC marked for attention of Technical Officer within six (6) months following completion of the investigation or at another approximate time as may be authorized by the Contracting Officer.

In addition to the above, appropriate articles relative to costs, funding levels, standard provisions, etc. will be added to the contracts as required.

Contract Exhibits

All data specifications are contained in the research proposals of those groups identified in the Technical Proposal Sections 1.1 and 1.2. No direct data except from these groups is required for completing the research objectives of this proposal.

7.0 OFFEROR REPRESENTATIONS AND CERTIFICATIONS

1. Small Business

That he is not a small business concern. Generally a small business concern for the purpose of Government procurement is a concern, including its affiliates, which is independently owned and operated, is not dominant in the field of operation in which it is submitting offers on Government contracts, and can further qualify under the criteria set forth in Code of Federal Regulations, Title 13, Part 121, as amended, which contains the detailed definition and related procedures. If offeror is a small business concern (1) and is not the

manufacturer of the supplies offered, it also represents that all supplies to be furnished hereunder will not be manufactured or produced by a small business concern in the United States, its Territories, its possessions, or Puerto Rico, and (2) it also represents that it has not previously been denied a Small Business Certificate by the Small Business Administration.

2. Regular Dealer

Not applicable.

3. Contingent Fee

a) That he has not employed or retained any company or person (other than a full-time bona fide employee working solely for the offeror) to solicit or secure this contract, and b) that he has not, paid or agreed to pay to any company or person (other than a full-time bona fide employee working solely for the offeror) any fee, commission, percentage, or brokerage fee, contingent upon or resulting from the award of this contract, and agrees to furnish information relating to a) and b) above as requested by the Contracting Officer. (for interpretation of the representation, including the term "bona fide employer", see Code of Federal Regulations, Title 41, Subpart 1-1.5.) (January 1964)

Execution of Standard Form 119: If the offeror, by checking the appropriate box provided therefor in his offer, has represented that he has employed or retained a company or person (other than a full-time bona fide employee working solely for the offeror-contractor) to solicit or secure this contract, or that he has paid or agreed to pay any fee, commission, percentage, or brokerage fee to any company or person contingent upon or resulting from the award of this contract, he may be requested by the Contracting Officer to furnish a completed Standard Form 119, "Contractor's Statement of Contingent or Other Fees". If the offeror has previously furnished a completed Standard Form 119 to the office issuing this Request

F

for Proposal, he may accompany his offer with a signed statement, a) indicating when such completed form was previously furnished, b) identifying by number the previous Request for Proposal or contract, if any, in connection with which such form was submitted, and c) representing that the statement in such form is applicable to this offer.

4. Type of Business Organization

That he operates as a corporation, incorporated in the State of Tennessee.

5. Buy American Certificate (January 1964)

The bidder or offeror hereby certifies that each end product, except the end products excluded below, is a domestic source end product (as defined in the contract clause entitled "Buy American Act"; and that components of unknown origin have been mined, produced, or manufactured outside the United States.

No excluded items.

NOTE: Specific information as to articles, materials, and supplies exempted from the Buy-American Act is available to prospective contractors upon request.

6. Contractor's Plant

Contractor's Plant is not in a Labor Surplus Area.

7. Equal Opportunity (October 1971)

Offeror has participated in a previous contract or subcontract subject either to the Equal Opportunity clause herein or the clause originally contained in section 301 of Executive Order No. 10925, or the clause contained in section 201 of Executive Order No. 1114; that he has filed all required compliance reports; and that representations indicating submission of required compliance reports, signed by proposed subcontractors, will be obtained prior to subcontract awards. (The above representation need not be submitted in connection with contracts or subcontracts which are exempt from the clause.)

8. Affirmative Action Program (October 1971)

(The following certification shall be completed by each offeror whose offer is $50,000 or more and who has 50 employees or more)

The offeror certifies that he has developed and maintained at each of his establishments Equal Opportunity Affirmative Action Programs, pursuant to 41 CFR 60.2.

9. Certification of Equal Employment Compliance (October 1971)

By submission of this offer, the offeror certifies that, except as noted below up to the date of this offer, no advise, information or notice has been received by the offeror from any Federal Government agency or representative thereof that the offeror or any of its division or affiliates or known first-tier subcontractors is in violation of any of the provisions of Executive Order No. 11246 of September 24, 1965, Executive Order No. 11375 of October 13, 1967, or rules and regulations of the Secretary of Labor (41 CFR, Chapter 60) and specifically as to not having an acceptable affirmative action program or being in noncompliance with any other aspect of the Equal Employment Opportunity Program. It is further certified and agreed that should there be any change in the status or circumstances certified to above between this date and the date of expiration of this offer or any extension thereof, the Government Contracting Officer cognizant of this procurement will be notified forthwith.

10. Certification of Nonsegregated Facilities

(Applicable to contracts, subcontracts, and to agreements with applicants who are themselves performing federally assisted construction contracts, exceeding $10,000 which are not exempt from the provisions of the Equal Opportunity Clause.)

By the submission of this bid, the bidder, offeror, applicant or subcontractor certifies that he does not maintain or provide for his employees any segregated facilities at any of his establishments, and that he does not permit his employees

to perform their services at any location, under his control where segregated facilities are maintained. He certifies further that he will not maintain or provide for his employees any segregated facilities at any of his establishments, and that he will not permit his employees to perform their services at any location, under his control, where segregated facilities are maintained. The bidder, offeror, applicant, or subcontractor agrees that a breach of this certification is a violation of the Equal Opportunity clause in this contract. As used in this certification, the term "segregated facilities" means any rooms, work areas, rest rooms and wash rooms, restaurants and other eating areas, time clocks, locker rooms and other storage or dressing areas, parking lots, drinking fountains, recreation or entertainment areas, transportation, and facilities provided for employees which are segregated by explicit directive or are in fact segregated on the basis of race, color, religion, or national origin because of habit, local custom or otherwise. He further agrees that (except where he has obtained identical certifications from proposed subcontractors for specific time periods) he will obtain identical certifications from proposed subcontractors prior to the award of subcontracts exceeding $10,000 which are not exempt from the provisions of the Equal Opportunity Clause; that he will retain such certifications in his files; and that he will forward the following notice to such proposed subcontractors (except where the proposed subcontractors have submitted identical certifications for specific time periods):

Notice to Prospective Subcontractors of Requirement for Certifications of Nonsegregated Facilities: A Certification of Nonsegregated Facilities must be submitted prior to the award of a subcontract exceeding $10,000 which is not exempt from the provisions of the Equal Opportunity clause. The certification may be submitted either for each subcontract or for all subcontracts during a period (i.e., quarterly, semiannually, or annually). (October 1971) (Note: The penalty

for making false statements in offers is prescribed in 18 U.S.C. 1001.)

11. Certificate of Independent Price Determination (Fixed-Price Proposal) (June 1964)

a) By submission of this bid or proposal, each bidder or offeror certifies, and in the case of a joint bid or proposal, each party thereto certifies as to its own organization, that in connection with this procurement:

1) The prices in this bid or proposal have been arrived at independently, without consultation, communication, or agreement, for the purpose of restricting competition, as to any matter relating to such prices with any other bidder or offeror or with any competitor;

2) Unless otherwise required by law, the prices which have been quoted in this bid or proposal have not been knowingly disclosed by the bidder or offeror prior to opening, in the case of a bid, or prior to award in the case of a proposal, directly or indirectly to any other bidder or offeror or to any competitor; and

3) No attempt has been made or will be made by the bidder or offeror to induce any other person or firm to submit or not to submit a bid or proposal for the purpose of restricting competition.

b) Each person signing this bid or proposal certifies that:

1) He is the person in the bidder's or offeror's organization responsible within that organization for the decision as to the prices being bid or offered herein and that he has not participated and will not participate, in any action contrary to a) 1) through a) 3) above; or

2) a) he is not the person in the bidder's or offeror's organization responsible within that organization for the decision as to the prices being bid or offered herein but that he has been authorized in writing to act as agent for the persons responsible for such decision in certifying that such persons have not participated, and will not participate, in any action contrary to a) 1) through a)3) above, and as their agent does hereby so certify; and

b) he has not participated and will not participate, in any action contrary to a)1) through a)3) above.

c) This certification is not applicable to a foreign bidder or offeror submitting a bid or proposal for a contract which requires performance or delivery outside the United States, its possessions, and Puerto Rico.

d) A bid or proposal will not be considered for award where a)1), a)3) or b) above has been deleted or modified. Where a)2) above has been deleted or modified, the bid or proposal will not be considered for award unless the bidder or offeror furnishes with the bid or proposal a signed statement which sets forth in detail the circumstances of the disclosure and the Administrator, or his designee, determines that such disclosure was not made for the purpose of restricting competition.

12. Place of Manufacture/Performance

Knoxville, Knox County, Tennessee.

13. Disclosure Statement--Cost Accounting Practices and Certification (May 1972)

Any contract in excess of $100,000 resulting from this solicitation, except when the price negotiated is based on: 1) established catalog or market prices of commercial items

sold in substantial quantities to the general public, or 2) prices set by law or regulation, shall be subject to the requirements of the Cost Accounting Standards Board. Any offeror submitting a proposal, which, if accepted, will result in a contract subject to the requirements of the Cost Accounting Standards Board must, as a condition of contracting, submit a Disclosure Statement as required by regulations of the Board. The Disclosure Statement must be submitted as a part of the offeror's proposal under this solicitation (see 1) below) unless i) the offeror, together with all divisions, subsidiaries, and affiliates under common control, did not receive net awards of negotiated defense prime contracts during the period July 1, 1970 through June 30, 1971 totaling more than $30,000,000 (see 2) below), ii) the offeror has already submitted a Disclosure Statement disclosing the practices used in connection with the pricing of this proposal (see 3) below), or iii) post-award submission has been authorized by the Contracting Officer. CAUTION: A practice disclosed in a Disclosure Statement shall not, by virtue of such disclosure, be deemed to be a proper, approved, or agreed to practice for pricing proposals or accumulating and reporting contract performance.

Certificate of Monetary Exemption: The offeror hereby certifies that, together with all divisions, subsidiaries, and affiliates under common control, he did not receive net awards of negotiated national defense prime contracts during July 1, 1970 through June 30, 1971 totaling more than $30,000,000.

14. By signature hereto, the Offeror certifies that all of the representations and certifications contained in his proposal are complete and accurate as required by this RFP and is aware of the penalty prescribed in 18 U.S.C. 1001 making false statements in proposals.

Name Hilton A. Smith

Hilton A, Smith

Title Vice Chancellor for Graduate Studies and Research

PART III

COST PROPOSAL

Attached herewith is a Cost Proposal in accordance with instructions outlined for submission of ERTS-B proposals.

DEPARTMENT OF DEFENSE

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Form Approved
Budget Bureau No. 22-R100

This form is for use when *(i)* submission of cost or pricing data *(see NASA PR 3.807-3)* is required and *(ii)* substitution for the DD Form 633 is authorized by the contracting officer.

PAGE NO. 1 | NO. OF PAGES 2

NAME OF OFFEROR	SUPPLIES AND/OR SERVICES TO BE FURNISHED
The University of Tennessee	Proposal Budget for ERTS-B Image Interpretation Techniques in the Tennessee Valley
HOME OFFICE ADDRESS *(Include ZIP Code)*	
Cumberland Avenue Knoxville, Tenn. 37916	
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED	**TOTAL AMOUNT OF PROPOSAL** / **GOVT SOLICITATION NO.**
Knoxville, Tennessee	$ 55,663

DETAIL DESCRIPTION OF COST ELEMENTS

				EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
1. DIRECT MATERIAL *(Itemize on Exhibit A)*						
a. PURCHASED PARTS						
b. SUBCONTRACTED ITEMS						
c. OTHER - (1) RAW MATERIAL						
(2) YOUR STANDARD COMMERCIAL ITEMS						
(3) INTERDIVISIONAL TRANSFERS *(At other than cost)*						
TOTAL DIRECT MATERIAL						
2. MATERIAL OVERHEAD [3] *(Rate % X $ base =)*						
3. DIRECT LABOR *(Specify)*	ESTIMATED HOURS	RATE/ HOUR	EST COST ($)			
Engineers	940	16.44	15,454			
Graduate Students	1,944	6.02	11,703			
Clerical	200	2.50	500			
Programmer	1,560	2.00	3,120			
TOTAL DIRECT LABOR					30,777	
4. LABOR OVERHEAD *(Specify department or cost center)* [3]	O.H. RATE	X BASE =	EST COST ($)			
The University of Tennessee	64.3	30,777	19,790			
TOTAL LABOR OVERHEAD					19,790	
5. SPECIAL TESTING *(Including field work at Government installations)*				EST COST ($)		
TOTAL SPECIAL TESTING						
6. SPECIAL EQUIPMENT *(If direct charge) (Itemize on Exhibit A)*						
7. TRAVEL *(If direct charge) (Give details on attached Schedule)*				EST COST ($)		
a. TRANSPORTATION 3 - 1 man trips						
b. PER DIEM OR SUBSISTENCE 3 - 1 man trips						
TOTAL TRAVEL					600	
8. CONSULTANTS *(Identity - purpose - rate)*				EST COST ($)		
TOTAL CONSULTANTS						
9. OTHER DIRECT COSTS *(Itemize on Exhibit A)*					4,496	
10. TOTAL DIRECT COST AND OVERHEAD						
11. GENERAL AND ADMINISTRATIVE EXPENSE *(Rate % of cost element Nos.)* [3]						
12. ROYALTIES [4]						
13. TOTAL ESTIMATED COST						
14. FEE OR PROFIT						
15. TOTAL ESTIMATED COST AND FEE OR PROFIT					55,663	

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)*

and reflects our best estimates as of this date, in accordance with the instructions to offerors and the footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
Dr. Hilton A. Smith, Vice-Chancellor for Graduate Studies and Research	Hilton A. Smith
NAME OF FIRM	**DATE OF SUBMISSION**
The University of Tennessee, Knoxville, TN. 37916	Jan. 26, 1973

DD FORM APR 65 633-4

(NASA EDITION)

EXHIBIT A - SUPPORTING SCHEDULE *(Specify. If more space is needed, use blank sheets)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST ($)
7	3 - 1 man trips from Knoxville to Washington for NASA	600
	briefings and NASA Seminars	
10	Computer time 10 hours @ $300/hour	3,000
10	Digital Tape 10 @ $25/tape	250
10	Publication Cost	200
10	General Administrative (Supplies, zeroxing, etc.)	300
10	Fringe Benefits - 10% of academic year	746
10	Salaries of faculty, plus permanent staff members. Excludes	
	summer salaries of 9-month appointment faculty or student	
	stipends. 10% of $7,455.	

I. HAVE THE DEPARTMENT OF DEFENSE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, OR THE ATOMIC ENERGY COMMISSION PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[X] YES [ ] NO *If yes, identify below.*

NAME AND ADDRESS OF REVIEWING OFFICE *(Include ZIP Code)*	TELEPHONE NUMBER/EXTENSION
DHEW 50 7th Street Atlanta, Ga. 30323	(404) 526-5822

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [X] NO *If yes, identify on a separate page.*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

[X] YES [ ] NO *If yes, identify:* [ ] ADVANCE PAYMENTS [X] PROGRESS PAYMENTS *OR* [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(or, do you have any independently financed (IR & D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT? [X] YES [ ] NO *If yes, identify* NAS5-21875

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN NASA PR, PART 15 *(see 3.807-2(c)(2))*?

[X] YES [ ] NO *If no, explain on a separate page.*

INSTRUCTIONS TO OFFERORS

1. The purpose of this form is to provide a standard format by which the offeror submits to the Government a summary of incurred and estimated cost *(and attached supporting information)* suitable for detailed review and analysis. Prior to the award of a contract resulting from this proposal the offeror shall, under the conditions stated in NASA PR 3.807-3, be required to submit a Certificate of Current Cost or Pricing Data (see NASA PR 3.807-3(e) and 3.807-4).

2. As part of the specific information required by this form, the offeror must submit with this form, and clearly identify as such, cost or pricing data (that is, data which is verifiable and factual and otherwise as defined in NASA PR 3.807-3(e)). In addition, he must submit with this form any information reasonably required to explain the offeror's estimating process, including:

   a. the judgmental factors applied and the mathematical or other methods used in the estimate including those used in projecting from known data, and

   b. the contingencies used by offeror in his proposed price.

3. When attachment of supporting cost or pricing data to this form is impracticable, the data will be specifically identified and described *(with schedules as appropriate)*, and made available to the contracting officer or his representative upon request.

4. The format for the "Cost Elements" is not intended as rigid requirements. These may be presented in different format with the prior approval of the contracting officer if required for more effective and efficient presentation. In all other respects this form will be completed and submitted without change.

5. By submission of this proposal, offeror, if selected for negotiation, grants to the contracting officer, or his authorized representative, the right to examine, for the purpose of verifying the cost or pricing data submitted, those books, records, documents and other supporting data which will permit adequate evaluation of such cost or pricing data, along with the computations and projections used therein. This right may be exercised in connection with any negotiations prior to contract award.

FOOTNOTES

1 Enter in this column those necessary and reasonable costs which in the judgment of the offeror will properly be incurred in the efficient performance of the contract. When any of the costs in this column have already been incurred (e.g., on a letter contract or change order), describe them on an attached supporting schedule. Identify all sales and transfers between your plants, divisions, or organizations under a common control, which are included at other than the lower of cost to the original transferor or current market price.

2 When space in addition to that available in Exhibit A is required, attach separate pages as necessary and identify in this "Reference" column the attachment in which information supporting the specific cost element may be found. No standard format is prescribed; however, the cost or pricing data must be accurate, complete and current, and the judgment factors used in projecting from the data to the estimates must be stated in sufficient detail to enable the contracting officer to evaluate the proposal. For example, provide the basis used for pricing materials such as by vendor quotations, shop estimates, or invoice prices; the reason for use of overhead rates which depart significantly from experienced rates (reduced volume, a planned major rearrangement, etc.); or justification for an increase in labor rates (anticipated wage and salary increases, etc.). Identify and explain any contingencies which are included in the proposed price, such as anticipated costs of rejects and defective work, or anticipated technical difficulties.

3 Indicate the rates used and provide an appropriate explanation. Where agreement has been reached with Government representatives on the use of forward pricing rates, describe the nature of the agreement. Provide the method of computation and application of your overhead expense, including cost breakdown and showing trends and budgetary data as necessary to provide a basis for evaluation of the reasonableness of proposed rates

4 If the total royalty cost entered here is in excess of $250 provide on a separate page (or on DD Form 783, Royalty Report) the following information on each separate item of royalty or license fee: name and address of licensor; date of license agreement; patent numbers, patent application serial numbers, or other basis on which the royalty is payable; brief description, including any part or model numbers of each contract item or component on which the royalty is payable; percentage or dollar rate of royalty per unit; unit price of contract item; number of units; and total dollar amount of royalties. In addition, if specifically requested by the contracting officer, a copy of the current license agreement and identification of applicable claims of specific patents shall be provided.

5 Provide a list of principal items within each category indicating known or anticipated source, quantity, unit price, competition obtained, and basis of establishing source and reasonableness of cost.

Exhibit 1

Date: January 26, 1973

Proposing Entity: The University of Tennessee
Knoxville, Tennessee 37916

COST/PRICE SUMMARY, ERTS-B DATA ANALYSIS

	Phase I	Phase II	Phase III	Total All Phases
NASA Share by Element of Cost				
Direct Labor Hours	240	554	3,850	4,644
Direct Labor Dollars	$ 1,315	$ 3,467	$ 25,995	$ 30,777
Overhead 64.3%	846	2,229	16,715	19,790
Material				
Subcontract				
Travel		200	400	600
Other Direct Cost	310	519	3,667	4,496
Subtotal				
G&A				
Subtotal				
Fee/Profit				
TOTAL NASA SHARE	2,471	6,415	46,777	55,663
COST SHARING (Funded by Other than NASA)				
Direct Labor Hours	-	-	-	-
Direct Labor Dollars	$ -	$ -	$ -	$ -
Other Costs	-	-	-	-
Total Funded by Other than NASA	$ -	$ -	$ -	$ -
Total Program (NASA and Other) Direct Labor Hours	240	554	3,850	4,644
Total Dollars	$ 2,471	$ 6,415	$ 46,777	$ 55,663

NASA Funds Required (Fiscal Year ended June 30)

FY 1974 $ 8,886 FY 1975 $ 37,500 FY 1976 $ 9,277 Total $ 55,663

Duration of Investigation

Proposed Start Date (Based on November 1973 Launch April, 1974 (month, year)

Phase I (Data Analysis Preparation) Duration 1 (months)

Phase II (Preliminary Data Analysis) Duration 2 (months)

Phase III (Continuing Data Analysis) Duration 15 (months)

TOTAL PROGRAM 18 (months)

Date: January 26, 1973

SCHEDULE A

Proposing Entity: University of Tennessee
Knoxville, Tennessee 37916

SCHEDULE OF DIRECT LABOR
BY QUARTER

COMPANY (Prime or Subcontractor)

-HOURS-

LABOR CLASSIFICATION	CY 1973					CY 1974					CY 1975					TOTAL LABOR		
	JFM	AMJ	JAS	OND	TOTAL	JFM	AMJ	JAS	OND	TOTAL	JFM	AMJ	JAS	OND	TOTAL	HOURS	RATE	AMOUNT
Engineer							130	230	120	480	120	120	220		460	940	16.44	15,454
Scientist																		
Research Assistant							324	324	324	972	324	324	324		972	1,944	6.02	11,703
Programmer							310	250	250	810	250	250	250		750	1,560	2.00	3,120
Technician																		
Clerical							30	30	30	90	30	30	50		110	200	2.50	500
Other																		
Total Direct Labor							794	834	724	2,352	724	724	844		2,292	4,644		30,777

Instructions for Preparation:

(A) A separate schedule may be prepared for each phase, or

(B) A single schedule may be prepared with separate totals for each phase

Date: January 26, 1973

Proposing Entity: University of Tennessee
Knoxville, Tennessee 37916

SCHEDULE A

SCHEDULE OF DIRECT LABOR
BY PHASE

COMPANY (Prime or Subcontractor)

LABOR CLASSIFICATION	Phase I		Phase II		Phase III		TOTAL	
	HOURS	DOLLARS	HOURS	DOLLARS	HOURS	DOLLARS	HOURS	DOLLARS
Engineer	30	493	100	1,644	810	13,317	940	15,454
Scientist								
Research Assistant	100	602	224	1,348	1,620	9,753	1,944	11,703
Programmer	110	220	200	400	1,250	2,500	1,560	3,120
Technician								
Clerical			30	75	170	425	200	500
Total Direct Labor	240	1,315	554	3,467	3,850	25,995	4,644	30,777

Instruction for Preparation:

(A) A separate schedule may be prepared for each phase, or

(B) A single schedule may be prepared with separate totals for each phase

LABOR RATE SUMMARY SCHEDULE A-1

Date: January 26, 1973

Proposing Entity: The University of Tennessee

The labor estimates used in the preparation of this proposal was based upon salaries and wages currently in effect at The University of Tennessee. A general increase rate of 5% was used as an escalation factor since the proposal spans two fiscal years.

The productive man-hours/year as established by The University of Tennessee is 1296 excluding vacations, holidays, etc.

SCHEDULE OF MATERIALS

Schedule B
Sheet 1 of 1

Date: January 26, 1973

Proposing Entity: University of Tennessee
Knoxville, Tennessee 37916

COMPANY (Prime or Subcontractor)

Schedule B not applicable since no direct material purchases are proposed.

SCHEDULE OF TRAVEL

Date: January 26, 1973
Proposing Entity: The University of Tennessee

SCHEDULE C
SHEET 1 OF 1

COMPANY (Prime or Subcontractor)

Origin/Destination	Purpose	No. of Persons	Fare	Amt.	Per Diem Days	Per Diem Rate	Per Diem Amt.	Local Travel Days	Local Travel Rate	Local Travel Amt.	Other-- Specify	Total	Date of Trip
3 1-man trips from Knoxville to Washington to attend NASA briefings and seminars												$ 600	
T O T A L												$ 600	

Date: January 26, 1973

Proposing Entity: University of Tennessee
Knoxville, Tennessee 37916

Schedule D
Sheet 1 of 1

SCHEDULE OF OTHER DIRECT COSTS

COMPANY (Prime or Subcontractor)

Description	Explanation	Amount
Computer Time	IBM System/360/65 10 hours @ $300/hour	$ 3000
Digital Tapes	9-track - 8 bpi compatible with above computer system. 10 @ $25/tape	250
Publication Costs	For printing, photography, etc. associated with publishing research results	200
Administration Expense	Supplies, telephone, zeroxing, etc.	300
Fringe benefits	10% of academic year salaries of faculty plus permanent staff members. Excludes summer salaries of 9-month appointment faculty or student stipends. 10% of 7455.	746
TOTAL		$ 4496

Date: January 26, 1973

Schedule E
Sheet 1 of 1

Proposing Entity: University of Tennessee
Knoxville, Tennessee 37916

SCHEDULE OF FIXED PRICE ITEMS

Schedule E not applicable to this proposal.

Date: January 26, 1973

Proposing Entity: University of Tennessee
Knoxville, Tennessee 37916

Schedule F-1
Sheet 1 of 1

OVERHEAD EXPENSE SCHEDULE

Officially audited overhead rate of 64.3% of salaries and wages by DHEW Audit Agency under Negotiation Agreement #88, date July 25, 1972 for the period July 1, 1973, predetermined through June 30, 1975.

Date: January 26, 1973

Schedule F-2
Sheet 1 of 1

Proposing Entity: University of Tennessee
Knoxville, Tennessee 37916

GENERAL AND ADMINISTRATIVE EXPENSE SCHEDULE

Not applicable to this proposal.

Date: January 26, 1973

Proposing Entity: University of Tennessee
Knoxville, Tennessee 37916

ADDITIONAL INFORMATION TO BE FURNISHED BY THE OFFEROR

Not applicable to this proposal.

Date: January 26, 1973

Proposing Entity: University of Tennessee
Knoxville, Tennessee 37916

SUMMARY OF DEVIATIONS/EXCEPTIONS IN THE COST/PRICE PROPOSAL

Not applicable to this proposal.